Space Education: Challenges and Strategies in Teaching Space Policy to Technical University Students

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Abstract

Law and policy provide the foundation for space actors engaging in space activities. Likewise, various levels of policy and regulation apply internationally, domestically, and even institutionally to both governmental and nongovernmental entities. Consequently, teaching the policy frameworks for space regulations and best practices is essential for a comprehensive university curriculum in space education. Challenges arise, however, when instructing technical and non-policy university students in humanities-centered topics. *Reading comprehension, writing ability, critical thinking*, and *communication skills* are critical elements of policy education, yet many technically oriented students struggle with these requirements. Given these are fundamental skillsets necessary for success in both academia and a dynamic space work force, adapting traditional teaching methodologies may be required to optimize desired learning outcomes for technical student audiences. Customizable strategies exist that can combine and scale these fundamental skillsets with substantive content and materials, providing a range of teaching and learning modalities for study, assessment, and experience. This presentation will highlight potential learning approaches tried at one aeronautical university to address these challenges.

For instance, overarching strategies may include commencing with a visual of the student journey (much like a user journey in an investment pitch) delineating the value-added experience for students engaging in course content, and building substantive skill-based learning components which are introduced sequentially and with increasing level of difficulty. Examples of learning methodologies include applying Bloom's Taxonomy in assignment creation. Most importantly: 1) *Knowledge*: involves identifying, understanding and remembering core content (e.g. pop quizzes, reading quizzes, cumulative review quizzes, question bank assessments); 2) *Analysis*: involves reading comprehension, interpretation, evaluation, analysis (e.g. essays, summaries, case studies); 3) *Application*: involves investigation, research and designing research projects (e.g. research articles, posters, digital presentations, short videos). Scaffolding assignments and artifacts into manageable pieces throughout the semester is key to guiding students towards success and reducing potential for 'expert blind spots.' Lastly, an end-of-course review and self-reflection of the student journey is helpful in underlining the critical thinking process and provide a visual review of the student journey in acquiring substantive knowledge, skills, and experience throughout the term.

Keywords
Space Policy, Space Education, Critical Thinking, Taxonomies of Learning

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1. Introduction

Course subjects in space law, policy and ethics form a unique but integral part of the Spaceflight Operations program at Embry-Riddle Aeronautical University (ERAU). Given the interdisciplinary nature of the program, course student enrollment comprises of Science, Technology, Engineering and Mathematics (STEM), as well as non-STEM and technical aviation students. Two introductory and mid-level law and policy courses are mandatory for majoring in the Spaceflight Operations program, which also attracts students outside the program seeking elective fulfilment in space related topics. Another two advanced courses are offered to Senior undergraduates and graduate students in applied space policy and regulation with requirements for original research and written analytical outputs.

As a technical institution, education is necessarily bifurcated into developing knowledge and applied skillsets at ERAU. In the policy and law courses students are educated in general law and policy concepts, specific international space treaty regimes, development of national space laws, space related agencies, and pertinent regulations. In addition, students conduct research; draft industry style reports and documents; discern the practical components and regulatory requirements for acquiring a license/permit for conducting spaceflight activities; compare/ contrast spaceflight activities and law/ policy implications across space companies, technologies, and mission architectures. Furthermore, students learn to identify and distinguish the pertinent values, interests and objectives impacting industry and government interrelationships and informing space policy development. So, while the core objective of the curriculum is knowledge based, inherent skillsets are required for both knowledge acquisition and practical application to successfully demonstrate competence in the course subject matter.

2. Teaching Challenges and Learning Strategies

Several challenges exist for industry experts and academics teaching professional and advanced policy related topics at a technical university. First, teaching humanities focused substantive content, even in a simplified format, is challenging without assessing and honing student core skillsets (significantly, reading and writing abilities). Secondly, student openness and willingness to adapt to new learning modalities as well as new substantive content, outside their comfort zone, is likewise challenging but essential. Ordinarily, law and policy courses are reading and writing intensive seminar classes, with critical analysis and discussion being central to the learning experience (e.g. Socratic Method). However, this traditional teaching method was not successful here and required adaptation given the university's program objectives and refocus on educating and training industry ready technicians, not academics or policy professionals. Course redesigns were therefore warranted utilizing Bloom's Taxonomy [1] in redefining course content and developing learning assignments and assessments in line with other technical courses in ERAU's College of Aviation. Ultimately, streamlined teaching approaches appealed more to students given their familiarity with this course structure and digital assessment formats. Student performance and satisfaction increased overall within a year of implementing these teaching modalities. The student learning experience and assessment plan was formatted around the core taxonomies of *knowledge, analysis,* and *application.*

2.1. Knowledge

Knowledge acquisition involved identifying, understanding, and remembering core content. Strategies to achieve knowledge retention included in-class pop quizzes (time restricted but open book); weekly reading quizzes (complete within multi-day window, two attempts permitted), based on current lectures and reading assignments; periodic cumulative practice quizzes based on course readings provided for memory review and retention at the end of each course section; and structured online assessments with the ability to test categories of knowledge using randomized questions from question banks to objectively gauge substantive learning. In summary, increasing opportunities for content repetition and recall were beneficial to student knowledge acquisition as demonstrated through objective grading of assignments.

2.2. Analyses

Analyses involved reading comprehension, interpretation, evaluation, and analysis. In these courses, analytical writing was best suiting to take home assignments, such as drafting analytical reports, synthesis and summary briefs, weekly reflections on news and policy

developments, examing case studies, and reading and critical thinking exercises etc. Higher level and graduate course requirements increasingly incorporate case studies/ scenarios with written assessments. Significantly, written analytical assignments were scaffolded for level of difficulty and in alignment with weekly course topics.

2.3. Application

Application involved individual and small group investigation, conducting research, expert interviews, and designing research projects. Applied assignments were particularly feasible and successful at the senior and graduate level. Assessments here included substantial hands-on outputs and artifacts including drafting an original conference-worthy research article, creating and delivering research posters, digital presentations and filming short student videos summarizing the students works on industry issues, scenarios, and policy issues.

3. Skill Set Requirements

The requisite skills required to address substantive learning in law, policy and ethics for spaceflight include: 1) critical thinking, 2) active reading, 3) analytical writing, 4) research skills, and 5) effective communication. These skillsets are focal to the core curriculum in both fundamental and advanced coursework. Furthermore, these skillsets are developed in tandem with substantive knowledge and scaffolded to improve on inherent weaknesses and build competencies. Examples of the skillset requirements with correlating learning challenges and applied learning strategies and assignments implemented are attached in Appendix A. The purpose, objectives and outputs of these skills sets were intentionally tiered throughout the course and developed by combining the seven learning strategies advanced by Ambrose et al. [2] and concepts from Martha Stassen's Program-Based Review and Assessment [3].

3.1. Critical thinking

Critical thinking is defined as reflective thought [4] and is essential here to both understanding law/ policy and being able to foresee implications of applied law, decision-making, and choosing courses of action/ inaction. In addition, critical thinking is key to understanding core issues and learning how to frame a question appropriately to find a valid answer.

3.2. Active Reading

Focused and active engagement in reading and class preparation is a challenge for many students. Learning strategies adopted here

(e.g. reading guides, quizzes) aimed to motivate and encourage student engagement and prepare for class meetings. Allowing two attempts at reading quizzes with pinpointed answers following the final attempt provided students with an opportunity to reflect on mistakes and ultimately be able to locate the correct answers in the assigned readings.

3.3. Analytical Writing

Analytical writing incorporated the prior two skillsets of substantive reading comprehension and reflective thought capabilities. Here correct knowledge must be applied and is evaluated for accuracy in form and substantive validity. Analytical approaches and exercises included variations on the analytical formula of issue, rule, analysis, conclusion (IRAC), and integrating evaluative approaches (comparing, contrasting, and distinguishing facts, issues, rules, cases) as used in law and policy. This analytical mindset/ skillset is taught in a manner that can be applied ubiquitously to any discipline or industry.

3.4. Research Skills

Developing strong and efficient research skills is universally key to any practice or discipline. Furthermore, this skillset inherently incorporates the skillsets of critical thinking and reading, and adapts analytical writing to creating concept maps, brainstorming research paper topics, formulating topical searches, evaluating sources, drafting research queries, and develops communication abilities with librarians and external experts for research purposes.

3.5. Effective Communication

This cumulative skillset is present in the previous skill tiers and culminates with the presentation of the acquired knowledge, and application of that knowledge. Effective communication, information and feedback provided on assessments to students were collated based on this author's experience and training with legal presentation skills, interpersonal communications, and drafting a wide range of academic, legal, and business documents. For instance, students are provided with a professional email template, complete with explanations for each line component and full sample communication, for applying in class communications and also for use in external professional communications.

3.6. Demonstration of Mastery

Ambrose et al. explain knowledge mastery as a three-tier learning process incorporating the acquisition of component skills, practice in integrating skills, and knowing how to apply skills [2]. Given the nature of law and policy as applied to an inherently unique and specific topic of spaceflight, this author takes the Mastery diagram one step further. Acquisition of knowledge and skills is impossible without the ability to also think out-side-the-box and understand the underlying values and concepts both informing space policy and law development and being impacted by the legislative process and industry objectives. Hence, the spheres of Mastery [Figure 1] have at their core the underlying values and concepts informing the perceptions for knowledge interpretation and application.
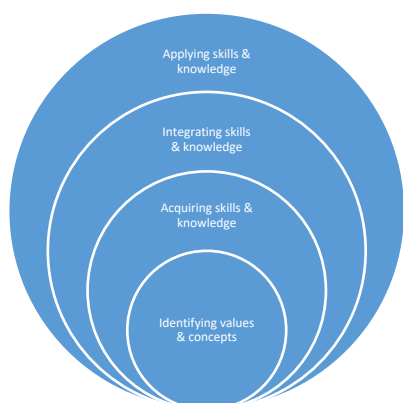

Figure 1. Mastery Diagram [1]

4. Further Considerations

Revising law/ policy curriculum and teaching strategies courses to suit a young technical audience can be daunting initially. Applicable course materials are limited for teaching at this level and forum, which means creativity and professional expertise are required simultaneously to teach the subject matter, and connect it to relevant forms (e.g. analogous examples, issues, rules, interpretations and authorities) for future applications. Lack of standardized textbooks or course materials for these courses also potentially leads to expert blind spots which must be identified and addressed. In addition, all materials must be sourced, evaluated and/or created by the instructor. This can present a heavy burden up front. Once the revision is completed, student assessments must also be monitored to ensure teaching effectiveness, taking into account class dynamics can impact overall performance outcomes and differ from term to term.

4.1. Expert Blind Spots

Expert blind spots are where the educator is not consciously aware of skills or knowledge required to complete a task [2]. This can manifest in omission of substantive information or failure to provide procedural steps to complete complex tasks. For example, unpacking core concepts and elements of law (e.g. negligence vs strict liability regimes) or utilizing professional language without explanation (e.g. legalese, industry terms of art, speed of articulation and comprehension). What is evident to an expert will not necessarily be clear to the student. Even ordinary terminology may lack clarity. For instance, one class struggled with the concept of a 'full sentence outline' and required a draft sample to follow before they understood the scope and purpose of the assignment. As a result, subject matter guides and sample provisions for even perceived basic skills are now provided to ensure student clarity and to demonstrate expectations (e.g. how to draft a paragraph, bibliography, abstract, brainstorm a mind/ concept map).

4.2. Evaluating and Curating Resources

Sourcing a range of digital resources is also an ongoing task for reinforcing lectures, course content and knowledge retention. Videos, podcasts, e-books, and digital products provide additional supplementary education. For instance, the United Nations' audiovisual library of international law space law series. Up to date authoritative publications and handbooks on space policy and law considerations for new space actors are limited, however, given the dynamic nature of policy and geopolitical support for national and commercial space objectives. However, recent resources help to simplify and highlight complex topics in space policy and law in digestible segments.

The benefit of curating these resources include making the overarching topics publicly accessible, available in a variety of consumable formats, and understandable to the ordinary layman. The challenge in surveying publicly available resources is that they tend to be very broad which may render superficial knowledge for the average student, and the illusion of knowledge can present a liability in practice. Conversely, if the content is too high level or dense the student loses interest quickly and has difficulty learning. Additionally, in conducting a search for quality educational space law and policy resources, it is clear that while some relevant space law/ policy resources exist, careful evaluation must be made to filter

through myriad opinion to provide accurate and objective informative for educational purposes. This is an ongoing examination for professionals and students alike. Not all publications or opinions are true, valid, or accurate. Consequently, "Evaluating Sources" has become a mandatory online training program required here to teach students how to effectively conduct research and screen current events, policies and evaluate source credibility and authority.

4.3. Additional Strategies

Three additional overarching strategies were initiated to help connect the dots in the student learning experience. First, presenting a visual demonstration of the student journey through the course. Secondly, articulating and explaining the class teaching philosophy, identifying key ethical approaches applicable to both life and educational learning. Lastly, creating an opportunity for students to reflect on their entering objectives and concluding self-assessment in the course.

4.3.1. Visualizing the Student Journey

Commencing each term with a visual aid or flow chart of the student journey has been helpful for delineating the value-added experience to encourage students to engage in the course, much like a user journey in an investment pitch. Here, the visual journey incorporated the substantive course content and milestone markers (e.g. assessments) demonstrated the consistent scaffolding of substantive knowledge and skill-based learning components which are introduced sequentially and with increasing level of difficulty.

4.3.2. Teaching Philosophy

Providing students in the introductory class with a chart identifying the professor's teaching philosophy and ethical values for the course, along with the rationale of those values and how they serve to improve quality of life experience both inside and outside the classroom (e.g. accountability, self-responsibility, openness to learning/relearning). While this knowledge is not new, the format and unpacking of the core values is often new information for students.

4.3.3. Student Reflections

Students are also asked to complete intake surveys identifying their academic status, career interests, and learning objectives in the course. Upon end of term, students are asked to reflect on their entrance surveys and articulate their self-evaluation of earlier goals and ultimate success. This student 'reflection' is distinguishable in form and purpose from the marketing style end-of-term student evaluations

provided by the institution. The aim here is to provide the opportunity for students to think critically and reflect ethically on their learning journey, see how far they have come in their knowledge and skill development, and/or hold themselves accountable for their performance in the course. These reflections are graded but designed as a pass/fail assignment to provide an incentive for participation.

5. Conclusions

In conclusion, teaching law and policy at a technical university is still an ongoing challenge. Adapting traditional and disciplinary teaching methods for a less humanities centered and more technically focused audience is inevitable. However, core taxonomies centered around knowledge acquisition, integration and analysis, and knowledge application to novel scenarios can provide an optimal structure for a curriculum redesign. Clearly identifying the core knowledge base and skillsets based on contemporary student knowledge, retention capacity and ability to connect learning to application can be customized successfully. Ultimately, scaffolding of content, assignments, and skillsets was key to optimizing the student learning experience and increasing student performance. As a work in progress, the teaching methods and modalities listed here are still under observation and will likely require tweaking based on class dynamics and program objectives going forward.

Acknowledgements

Appendix

Appendix A Example Teaching Strategies

References

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Appendix A Example Teaching Strategies

Ex. Skillset Requirements	Ex. Learning Challenges	Ex. Learning Strategies
Critical Thinking	Knowledge identification, comparison; distinguishing facts, values, positions, statements etc.; applying rational thought analysis (e.g. if we accept x, then what?); framing intelligent questions	• Attention to detail exercises (e.g. issue spotting, rule spotting) • Drafting questions/reflections • Evaluating written sources (popular news posts, blogposts, scholarly articles • Evaluative assessment questions • Scenario based questions • Case study analysis
Active Reading	Reading comprehension, speed reading,	• Note taking/ reading guides • Chapter summaries/ outlines • Reading quizzes • In-class pop quizzes • Cumulative review quizzes
Analytical Writing	Substantive reading, reflection, analytical writing skills (e.g. IRAC, CRAC, FRAC)	Drafting assignments • Topic explanations • Abstract proposals • Full-sentence outlines • Annotated bibliographies • Policy briefs/ industry briefs • Analytical research papers
Research skills	Critical thinking, reading comprehension, evaluating sources, library and digital resource skills	• Digital research skill trainings • Library research trainings (e.g. video modules/certification, in person training) • Subject Matter research guides/ How To Research Guides • Substantive website review (e.g. UNOOSA website) • Research tasks (e.g. research quizzes, summaries) • Annotated bibliographies
Effective Communication	Clear, effective, collaborative communication, distinguishing audience, appropriate communication style, communication modalities (e.g. instrument form, function, persuasiveness)	• Class communication policy • Basics on communication etiquette (with example digital communications templates) • Peer review (written, verbal) • Guided course surveys, reflections, evaluations • Posters presentations • Papers presentations • Short video summaries