On the use of drones in integrated STEM education

A perspective from various theoretical lenses

Benson Wallace
American College of Education - SCI5213

Introduction

- We will describe and analyse the following educational theories in the context of (where possible) the educational use of drones in integrated STEM:
  - Pedagogy
  - Andragogy
  - Multiple Intelligences
  - Social Learning
  - Social Exchange
- Some clarifications before we start:
  - The use of drones (or UAVs) is a sub-branch of educational robotics (Miah, 2020)
  - The literature cited is as “robotics-specific” (or at least STEM-specific) as possible, but some examples will necessarily be generic.
  - Where relevant I have included the title of the reference in addition to the author

Defining pedagogy in context

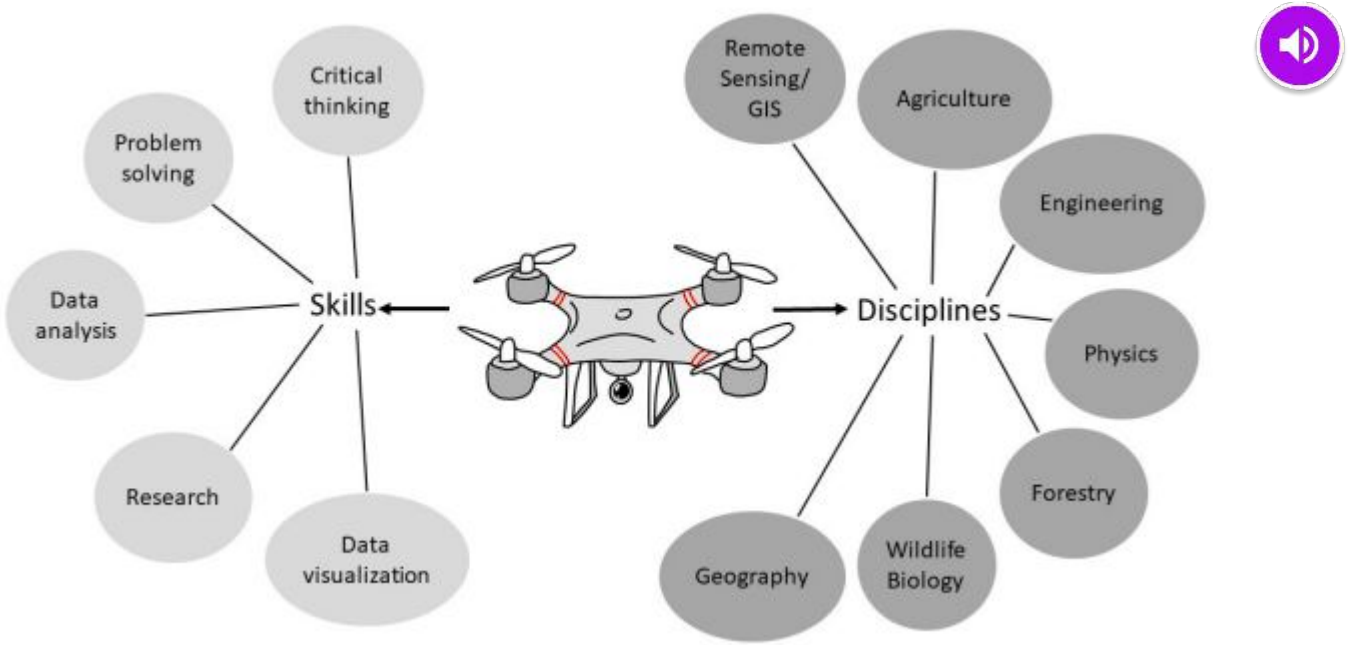
“...in contrast to didactics where the focus is on teachers’ role and activity, pedagogy is a broader term that also encapsulates activities and processes from the perspective of the learners” (Dobrosovestnova, 2019) - from “Constructivism* in Educational Robotics. Interpretations and Challenges”.

“...multicopters provide an intersection of STEM principles that can be used as a theme that ties lessons from across disciplines together and a place to teach science and mathematics concurrently with technology and engineering design-based pedagogies.” (Sutton et al., 2016) - from “multicopter design challenge: design, fly and learn”.

Tying the STEM disciplines together

Figure 1

Concept map of skills and disciplines that can be taught through drones



Note. Adapted from Bolick et al. (2022)

Strategies for applying pedagogy in context

	Strategy Examples
Possible didactic (teaching) strategies	● Use as a “nesting doll” for STEM concepts (Schroyer, 2013, para. 3) ● Students could use it to create a concept map for integrated STEM ● Students could be given a design brief with desired specs for a drone product and apply the design cycle in project teams
Engagement strategy #1 for diverse learners	Be sure to cater to both “traditionally academic” students and also those who are more inclined to “learn by doing”, “get their hands dirty” etc.
Engagement strategy #2 for diverse learners	Allow students to specialise according to their interests - some might like do dive deep into the coding aspect of drone design and operation, while others might be more inclined to work on the product marketing materials.

Defining andragogy in context

Key distinguishing feature of andragogy vs pedagogy is that of independent (self-regulated) vs dependent learners, but even being self-regulated isn't enough in an integrated STEM context (Delahunty and Kimbell, 2021) - from "(Re)framing a philosophical and epistemological framework for teaching and learning in STEM: Emerging pedagogies for complexity".

Integrated STEM as a complex adaptive system (CAS) requires heutagogy (facilitating self-determined or self-managed learning) as opposed to andragogy (Humble and Mozelius, 2021) - from "Enhancing Pedagogy to Andragogy in the Redesign of Teacher Training Courses on Programming"

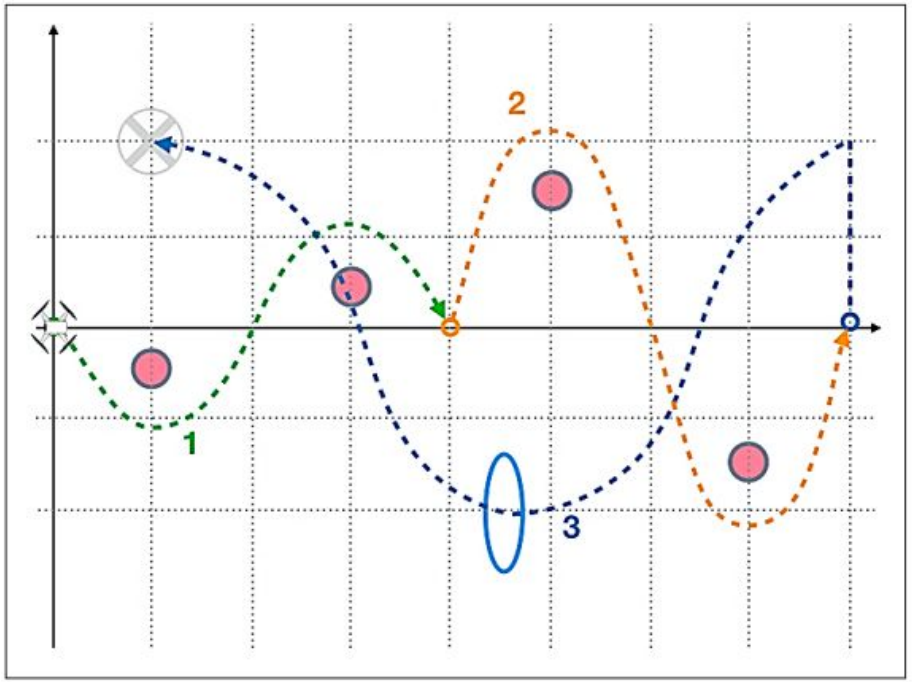
Strategies for applying andragogy in context

	Strategy Examples
Possible didactic (teaching) strategies	For upper high school students, it is appropriate to use a blend of pedagogy and andragogy (International Baccalaureate Organization, 2015)
Engagement strategy #1 for diverse learners	Delahunty and Kimbell (2021) noted that heutagogic practice (which by definition engages a diverse range of learners) naturally emerges in design and technology classes - hence, let students make more design decisions in science and mathematics classes!
Engagement strategy #2 for diverse learners	Yepes et al. (2021) used drones in an innovative way to teach trigonometric functions to high school students; the context for the “workshops”, as they called them, was a drone programming problem. This transformed a traditional mathematics lesson into a problem-based learning context, a preferred approach of andragogy (International Baccalaureate Organization, 2015).

Transforming trigonometry into problem-based learning

Figure 2

Programming drones to avoid obstacles using sinusoidal functions



Note. Adapted from Yepes et al. (2021)

Defining multiple intelligence theory in context

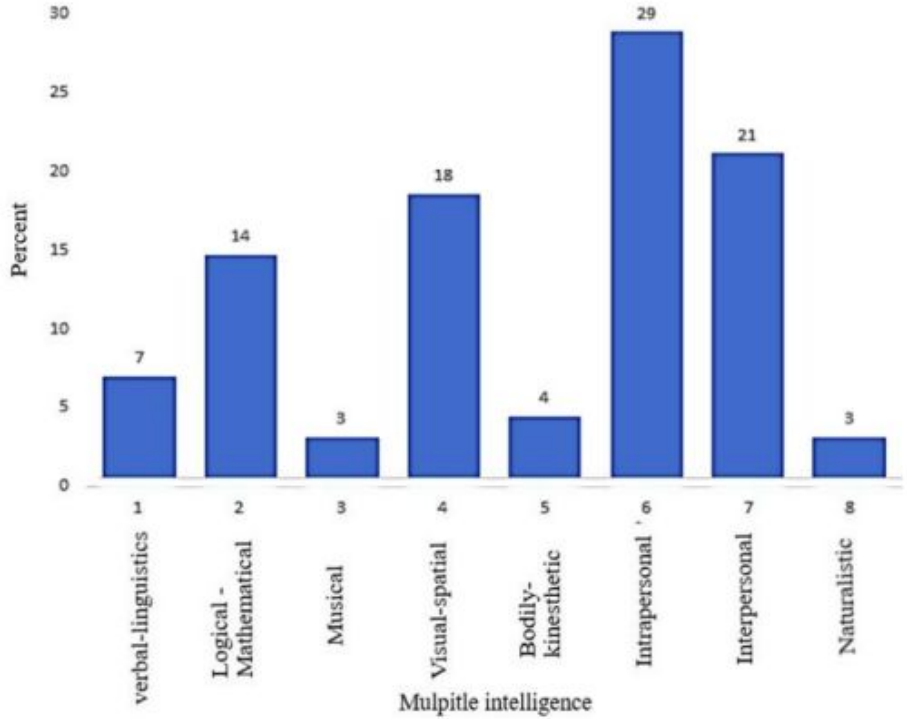
- Students in contemporary classrooms are most likely to be taught by teachers who have well developed verbal-linguistic or logical-mathematical intelligence (the dominant forms assessed by conventional education) (Bellanca, 2009)

- Modifying learning experiences and assessments for multiple intelligences as a form of differentiation (Balgan et al., 2022)

Surveying for multiple intelligences

Figure 3

Distribution of Gardner's 8 intelligences in a sample of undergraduate students



Note. Adapted from Balgan et al. (2022)

Strategies for applying multiple intelligences in context

	Strategy Examples
Possible didactic (teaching) strategies	Survey your own classes in the same way that Balgan et al. did, and think about what tweaks and modifications you could make to the learning experiences you currently use that would engage each of the multiple intelligence types present in your classroom.
Engagement strategy #1 for diverse learners	Assign roles that play to students' multiple intelligence strengths - for example, bodily-kinesthetic learners could be drone pilots, and visual-spatial learners could be responsible for design sketches or 3D modelling.
Engagement strategy #2 for diverse learners	Consider unconventional ways to involve the multiple intelligences not typically associated with STEM disciplines (musical, naturalist, and interpersonal, for example) - could such students produce a music video? Design a drone for ecosystem monitoring perhaps? Could someone with strong interpersonal skills be the project manager?

Defining social learning theory in context

- In a nutshell - people learn by observing and then modeling the behaviour of others (Kretchmar, 2021)
- This connects to Ritchhart's (2015) notion of Modeling as one of the 8 Cultural Forces that has the potential to transform schools into ones that possess "cultures of thinking" - more than just modeling skills and processes, teachers must *be* models of thinking and learning, and model for students *how* scientists and engineers think
- Social learning theory reconciles with the idea of learning science by doing scientific inquiry (Rumjaun and Narod, 2020)

Strategies for applying social learning theory in context

	Strategy Examples
Possible didactic (teaching) strategies	Model the practice of “tinkering” with drones for students. Share the struggles that you went through in your own learning process with them. Be the amateur inventor that you’d like them to become. Come up with your own application idea and work on it alongside your students as they work on their projects.
Engagement strategy #1 for diverse learners	Highlight the stories of the diverse range of people who are out there experimenting with drones. Consider joining an online club or competition.
Engagement strategy #2 for diverse learners	Find a good role model from industry who could visit your class. If that isn’t possible, beam one (or several) in via Skype a Scientist.

Defining social exchange theory in context

- Social cost-benefit analysis; assumes that people are rational economic actors; one of the key ideas is reciprocity (Miller, 2022, Reddick et al., 2018)
- Most education-related research thus far relates to adult learners (Reddick et al., 2018, Elstad et al., 2011)
- Professor Lee Waller (2013) outlines some implications of social exchange theory for educators in general:
    - Students will do a cost-benefit analysis on what you're asking them to learn
    - The idea of reciprocity applies to teacher-student relationships - learning contracts?

Strategies for applying social exchange theory in context

	Strategy Examples
Possible didactic (teaching) strategies	As STEM teachers we are asking students to invest time and mental effort into learning hard things. Leveraged in the right way, drones could provide a way to add weight to the “benefit” side of their cost-benefit analysis. Perhaps start the unit by asking students to imagine the possibilities and opportunities that mastery of drones could bring into their lives. Also, leverage the idea of reciprocity by setting up group work that requires interdependence.
Engagement strategy #1 for diverse learners	Be sure to present a balanced view of the potential benefits of drones (that is, other than lucrative business and career opportunities). Some students may be more motivated by the potential social or environmental impact. Consider linking student projects to the UN Sustainable Development Goals.
Engagement strategy #2 for diverse learners	Have students source and share project ideas from their own communities. They could gather data from their respective communities as part of the research phase of the design cycle. This leverages the diversity in your school community and ensures that diverse viewpoints are included in the project.

Conclusion

- Considering a planned integrated STEM unit from the perspective of different educational theories can provide inspiration for a variety of ways to differentiate instruction and engage diverse learners
- Many examples of STEM-specific approaches can be adapted from the literature - don’t reinvent the wheel unless you have to!
- Specifically considering strategies to engage diverse learners in each case can redistribute the focus of STEM instruction away from its current dominant culture focus

References

- Balgan, A., Renchin, T., & Ojgoosh, K. (2022). An Experiment in Applying Differentiated Instruction in STEAM Disciplines. Eurasian Journal of Educational Research (EJER), 98, 21–37.
- Bellanca, J. (2009). 200+ Active Learning Strategies and Projects for Engaging Students' Multiple Intelligences. Corwin.
- Bolick, M. M., Mikhailova, E. A., & Post, C. J. (2022). Teaching innovation in STEM education using an unmanned aerial vehicle (UAV). Education Sciences, 12(3), 224. https://doi.org/10.3390/educsci12030224
- Delahunty, T., & Kimbell, R. (2021). (Re)framing a philosophical and epistemological framework for teaching and learning in STEM: Emerging pedagogies for complexity. British Educational Research Journal, 47(3), 742–769. https://doi.org/10.1002/berj.3706
- Dobrosovestnova, Anna. (2019). "Constructivism in Educational Robotics. Interpretations and Challenges". 10.13140/RG.2.2.32197.88800.
- Elstad, E., Christophersen, K. A., & Turmo, A. (2011). Social exchange theory as an explanation of organizational citizenship behaviour among teachers. International Journal of Leadership in Education, 14(4), 405–421. https://doi.org/10.1080/13603124.2010.524250
- Humble, Niklas & Mozelius, Peter. (2021). Enhancing Pedagogy to Andragogy in the Redesign of Teacher Training Courses on Programming. 10.34190/EEL.21.032.
- International Baccalaureate Organization. (2015, February). Approaches to teaching and learning in the Diploma Programme. https://xmltwo.ibo.org/publications/DP/Group0/d_0_dpatl_gui_1502_1/static/dpatl/img/files/en/d_0_dpyyy_gui_1412_1_e.pdf
- Kretchmar, J. (2021). Social Learning Theory. Salem Press Encyclopedia.

References

- Miah, A. (2020, June 19). Drones are robots too! University of Salford Manchester. https://www.salford.ac.uk/news/drones-are-robots-too.
- Miller, S. P. (2022). Social exchange theory. Salem Press Encyclopedia.
- Reddick, R. J., Struve, L. E., Mayo, J. R., Miller, R. A., & Wang, J. L. (2018). “We Don’t Leave Engineering on the Page”: Civic Engagement Experiences of Engineering Graduate Students. Journal of Higher Education Outreach and Engagement, 22(2), 127–155.
- Ritchhart, R. (2015). Creating cultures of thinking: The 8 forces we must master to truly transform our schools (1st ed.). John Wiley & Sons.
- Rumjaun, A., Narod, F. (2020). Social Learning Theory—Albert Bandura. In: Akpan, B., Kennedy, T.J. (eds) Science Education in Theory and Practice. Springer Texts in Education. Springer, Cham. https://doi.org/10.1007/978-3-030-43620-9_7
- Schroyer, M. (2013, September 24). Drones for schools. Robohub. Retrieved July 17, 2022, from https://robohub.org/drones-for-schools/
- Sutton, Kevin & Busby, Joe & Kelly, Daniel. (2016). Multicopter design challenge: Design, fly, and learn.. Technology and Engineering Teacher, 76(2), 8-12.. 76. 8-12.
- Waller, L. [Lee Rusty Waller]. (2013, September 3). 4 educational implications of social exchange theory [Video]. YouTube. https://www.youtube.com/watch?v=1qgPfLAi4EA
- Yepes, I., Barone, D. A. C., & Porciuncula, C. M. D. (2021). Use of drones as pedagogical technology in STEM disciplines. Informatics in Education, 21(1), 201–233. https://doi.org/10.15388/infedu.2022.08