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Creative ways to study for an acoustics qualifying exam

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Studying for a doctoral qualifying exam in acoustics can be an imposing task for graduate students. Many students prepare for their qualifying exam by reading acoustics textbooks, reviewing class notes, and solving practice problems. The authors synthesized these conventional modes of study into creative activities when preparing for their own qualifying exams: PGK recorded video derivations and CAG assembled a website. The authors outline the value of creativity in learning and share how their creative projects helped them revise their fundamentals, deepen their understanding, synthesize new ideas, and acquire a more holistic view of acoustics. Suggestions are offered for how other students can study creatively for their own exams.

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1. INTRODUCTION

The Graduate Program in Acoustics at the University of Texas at Austin (UT Austin) requires that doctoral students pass a qualifying exam around the end of their second academic year. The exam consists of a four-hour written exam covering physical acoustics, math, and two elective areas, followed by an hour-long oral exam. Qualifying exams at other universities have similar structures.

Studying for a qualifying exam yields many educational benefits, five of which are highlighted below:

1. Reviewing graduate-level coursework in acoustics, as well as undergraduate-level physics, math, and engineering, gives students the chance to solidify their fundamentals and address weak areas.
2. Reflecting on coursework allows students to more deeply explore topics that may have initially been covered at an introductory level.
3. Revisiting coursework in view of students' research experiences stimulates new perspectives that are beneficial to the field of acoustics.
4. Simultaneously studying physical acoustics, math, and the two electives lets students appreciate both the broadness and interconnectedness of acoustics.
5. Presenting solutions and arguments clearly and convincingly strengthens scientific communication skills.

The authors found that creative forms of studying helped them achieve the above outcomes. CAG designed a website of original problems and solutions covering linear and nonlinear acoustics, ultrasonics, and math, while PGK produced videos of important derivations related to physical acoustics.

The value of creativity in learning is discussed in Sec. 2. CAG and PGK in Secs. 3 and 4 discuss how their creative projects helped them revise their fundamentals, deepen their understanding, synthesize new ideas, and acquire a more holistic view of acoustics. Additional suggestions for creative studying are offered in Sec. 5.

2. THE VALUE OF CREATIVITY IN LEARNING

In modern education research, the relevance of creativity to learning can be traced to the development of Bloom's taxonomy in 1956.[1] The taxonomy organizes educational objectives in order of increasing complexity in the learning process: knowledge, comprehension, application, analysis, synthesis, and evaluation. Each objective builds upon the lower objective. The fact that "synthesis" appears near the top of the taxonomy suggests that creation builds upon the more rudimentary educational objectives. A revision to Bloom's taxonomy proposed in 2001 by Anderson et al.[2] further emphasizes the importance of creation by reversing the role of "synthesis," now titled "create," and "evaluation," and by using verbs rather than nouns to describe the cognitive processes, as shown in Fig. 1. Anderson et al. write that in the "create" process, "the student must draw upon elements from many sources and put them together into a novel structure or pattern relative to his or her own prior knowledge. *Create* results in a new product, i.e., something that can be observed and that is more than the student's beginning materials."[2]

Creation is a central component of other education ideologies. Constructionism, for example, asserts that students are "most likely to become intellectually engaged" when creating,[3] while Interest-Driven Creator Theory[4] emphasizes that "when we create ideas or artifacts, the experience alters and enriches our background knowledge; in other words, we learn... Creation is the actual learning process."[5] From the perspective of educational psychology, creative activities have been shown to promote memory consolidation, critical thinking, communication skills, and problem solving skills.[6–10] Creative activities can also improve one's subjective well-being[11] and foster positive mental health.[12] Educational psychologist R. A. Beghetto

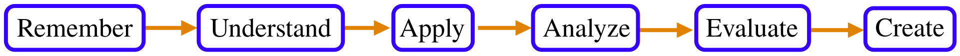

Figure 1: Revised Bloom's taxonomy.[2] Elements of the learning process are listed in order of increasing complexity, where creative activity is regarded as the most sophisticated cognitive process.

highlights the broad impact of creativity in learning, writing that creative activities lead to "new and meaningful contributions to one's own and others' learning and lives."[13]

One example of creative activity in learning is the creation of digital artifacts, like websites and videos. The storytelling, artwork, and animation involved in the creation of these media have been shown to improve learning outcomes.[14–17] In Secs. 3 and 4, the authors illustrate how the benefits of creativity described above enrich the learning outcomes listed in Sec. 1.

3. WEBSITE

CAG prepared for his qualifying exam in the summer of 2023 and was motivated to find a creative outlet for his studies after reading S. Schoen Jr.'s *Georgia Tech Mechanical Engineering Quals Review Book*.[18] Inspired by the traditional HTML design and the interactive nature of physics and engineering websites like *Hyperphysics*, *Continuum Mechanics (with emphasis on metals & viscoelastic materials)*, and *Acoustics and Vibration Animations*, CAG designed a website that covers the content he would be responsible for on his exam. The website contains original practice problems inspired by class notes and textbooks and is organized into the following pages:[19]

- The Physical Acoustics page covers content taught by M. F. Hamilton in *Acoustics I* and *II*, two first-year graduate-level courses in acoustics offered at UT Austin.[20] The page is indexed following the organization of Blackstock's *Fundamentals of Physical Acoustics*,[21] which serves as the primary reference for the *Acoustics I* and *II* courses. Additional content is adapted from the *Feynman Lectures on Physics*,[22] Pierce's *Acoustics: An Introduction to Its Physical Principles and Applications*,[23] Morse and Ingard's *Theoretical Acoustics*,[24] and Schroeder's *An Introduction to Thermal Physics*.[25]
- The Ultrasonics page covers most of the content taught by M. R. Haberman in his graduate-level course on ultrasonics at UT Austin.[26] Content is also adapted from Bedford and Drumheller's *Introduction to Elastic Wave Propagation*.[27]
- The Nonlinear Acoustics page covers content taught by M. F. Hamilton in his graduate-level course on nonlinear acoustics.[28] The webpage consists primarily of qualitative questions about the progressive wave equations used to model nonlinear acoustic wave phenomena. Quantitative questions are available in the documents linked on the webpage. Additional content is adapted from Hamilton and Blackstock's *Nonlinear Acoustics*.[29]
- The Math page is organized in order of increasing difficulty, beginning with high-school level algebra and calculus and ending with partial differential equations. The section on Fourier series and transforms includes problems from Boas's *Mathematical Methods in the Physical Sciences*.[30] The section covering linear algebra is inspired by Strang's *An Introduction to Linear Algebra*,[31] as well as the appendix of Griffiths's *Introduction to Quantum Mechanics*.[32] The section on ordinary differential equations is based on class notes from D. Rachinskiy's undergraduate course at UT Dallas,[33] and the sections on special functions and vector calculus are inspired by Chap. 1 of Griffiths's *Introduction to Electrodynamics*.[34]

The creativity involved in designing a website enlivens the potentially tedious process of solidifying one's fundamentals. The joy derived from creating illustrations, like those shown in Fig. 2, alleviates the difficulty

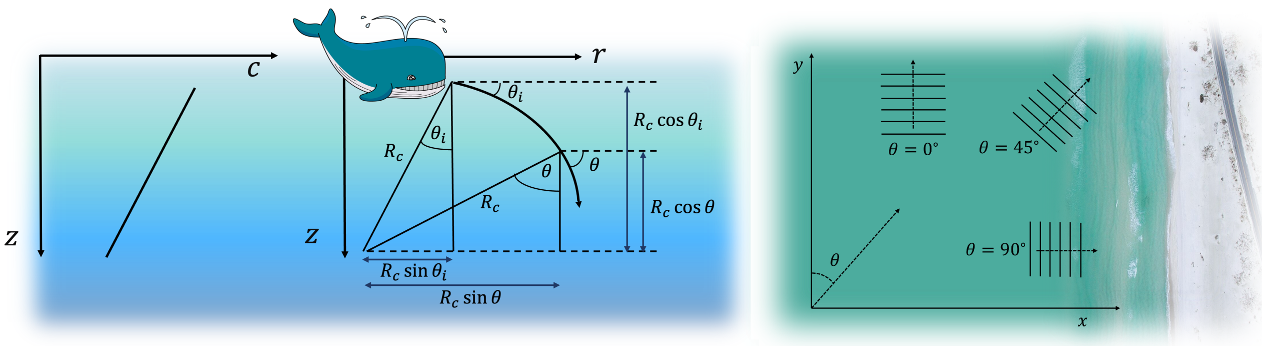

Figure 2: Creative illustrations from (left) Chap. 8 of the Physical Acoustics webpage of ray propagation in the ocean for a linear dependence of sound speed c on depth z, based on Fig. 8.8 of Ref. 21, and (right) Chap. 6 of ocean waves traveling at different angles θ with respect to the shoreline as a means to discuss the phase and group speed of waves.

associated with addressing weak areas, enriching Objective 1 of the educational outcomes listed in Sec. 1. The prospect of sharing the resulting webpage with peers, friends, and family encourages the student to take ownership of the content, which inspires the student to more deeply understand the material and furthers Objective 2. The visual appeal of the HTML format encourages the student to step back and appreciate the content that has been mastered, and to reflect on how one's research experiences relate to what has been taught in class. Such reflections may stimulate original ideas that are beneficial to the acoustics community, enriching Objective 3. In CAG's case, reflection on Prob. 3 of Chap. 12 in view of his research of vortex beams[35,36] has led to ongoing research. The categorization of topics in tables of contents highlights the broadness of acoustics, while hyperlinking sections and equations draws attention to the interconnectedness of wave phenomena, enhancing Objective 4. Finally, the website's expandable content allows for clear, step-by-step solutions to be included, strengthening communication skills and enriching Objective 5.

4. VIDEOS

CAG's website inspired PGK to find a creative outlet for his studying in the summer of 2024. PGK decided to create a series of video derivations covering topics in physical acoustics, resulting in a YouTube channel titled "Acoustics Derivations."[37] The videos are recorded in a traditional lecture format, in which PGK presents derivations from first principles without the aid of notes. Examples of popular videos include "General Solution to the Wave Equation," "Energy Density in A Sound Wave," and "Impedance of a Spherical Wave."

PGK found that recording the derivations, designing the banner and logo shown in Fig. 3, and composing a jingle (which can be heard at the start of the videos) makes studying enjoyable and artistic, augmenting Objective 1 of the educational outcomes. The availability of the YouTube videos to the public encourages the student to feel responsible for the material presented, promoting academic rigor and strengthening Objective 2. At the time of writing, PGK's videos have currently amassed over 200 views. The editing process also gives the student the opportunity to review the recorded derivations, allowing for a self-assessment and indicating to the student where understanding can be deepened. The ease with which the videos can be shared with other students stimulates discussion of alternative approaches toward obtaining and interpreting results, enriching Objective 3. YouTube's video gallery allows for the student to appreciate the diversity of topics covered, and the ability to create playlists allows for videos to be categorized by topic, enhancing Objective 4. The skill of clearly presenting scientific information furthers Objective 5 and has positively impacted PGK's doctoral research.[38]

Figure 3: Banner (left) and logo (right) for PGK's YouTube channel, "Acoustics Derivation."

5. SUGGESTIONS FOR CREATIVE STUDYING

The authors have discussed how designing a website and producing videos enhance the educational objectives of a qualifying exam. The value of the resources created extends beyond the exam, and the authors and their peers continue to refer to the website and videos after having passed their exams. Below are suggestions for additional ways students can study creatively for their qualifying exams:

- Digitize and organize handwritten class notes into a textbook, as done in Ref. 18. To obtain a more holistic view of acoustics, cross-reference equations and create an index.
- Create figures or animations depicting wave phenomena. By focusing on the details, subtleties, and aesthetics of figures and animations, one gains a thorough understanding of the physical processes.
- Produce a weekly podcast or blog in which a topic of study is discussed. The process of verbalizing derivations and wave phenomena can help make quantitative concepts more qualitative, which can be beneficial in preparation for an oral qualifying exam.
- Present informal lectures to fellow students without the aid of notes. Presenting derivations to other students strengthens communication skills and confidence while also benefiting the audience, who may gain new perspectives from the derivations. More experienced students can also provide feedback on the delivery of the derivation.
- Write a song or simple melody to help recall derivations. While lighthearted, lyrics set to a simple melody can lead to increased memory recall.[39]

The authors welcome feedback on their creative projects. They hope that the resources they created continue to benefit others, and they encourage fellow students to find creative outlets in their own studies.

Students: Get creative with your learning!

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CONFLICT OF INTEREST

The authors have no conflicts to disclose.

DATA AVAILABILITY

The data that support the findings of this study are available within the article.

REFERENCES

[1] B. S. Bloom (ed), M. D. Engelhart, E. J. Furst, W. H. Hill, and D. R. Krathwohl. *Taxonomy of Educational Objectives: The Classification of Educational Goals: Handbook 1: Cognitive Domain*. David McKay Company, Inc., 1956.

[2] L. W. Anderson (ed), D. R. Krathwohl (ed), P. W. Airasian, K. A. Cruiskshank, R. E. Mayer, P. R. Pintrich, J. Raths, and M. C. Wittrock. *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives*. Addison Wesley Longman, Inc., abridged edition, 2001.

[3] Y. B. Kafai and M. Resnick. Introduction. In Y. B. Kafai and M. Resnick, editors, *Constructionism in Practice: Designing, Thinking, and Learning in a Digital World*, pages 1–8. Lawrence Erlbaum Associates, Inc., 1996.

[4] T.-W. Chan, C.-K. Looi, W. Chen, L.-H. Wong, B. Chang, C. C. Y. Liao, H. Cheng, Z.-H. Chen, C.-C. Liu, S.-C. Kong, H. Jeong, J. Mason, H.-J. So, S. Murthy, F.-Y. Yu, S. L. Wong, R. B. King, X. Gu, M. Wang, L. Wu, R. Huang, R. Lam, and H. Ogata. Interest-driven creator theory: towards a theory of learning design for Asia in the twenty-first century. *J. Comput. Educ.*, 5:435–461, 2018.

[5] T.-W. Chan, C.-K. Looi, B. Chang, W. Chen, L.-H. Wong, S. L. Wong, F.-Y. Yu, J. Mason, C.-C. Liu, J.-L. Shih, Y.-T. Wu, S.-C. Kong, L. Wu, T.-C. Chien, C. C. Y. Liao, H. Cheng, Z.-H. Chen, and C.-Y. Chou. IDC theory: creation and the creation loop. *Res. Pract. Technol. Enhanc. Learn.*, 14:1–29, 2019.

[6] M. Tzachrista, E. Gkintoni, and C. Halkiopoulos. Neurocognitive profile of creativity in improving academic performance - a scoping review. *Educ. Sci.*, 13, 2023. Article number 1127.

[7] S. Padget. An introduction to creativity and critical thinking. In S. Padget, editor, *Creativity and Critical Thinking*, pages 1–15. Routledge, 2013.

[8] P. Ellerton and R. Kelly. Creativity and Critical Thinking. In A. Berry, C. Buntting, D. Corrigan, R. Gunstone, and A. Jones, editors, *Education in the 21st Century: STEM, Creativity and Critical Thinking*, pages 9–27. Springer, 2021.

[9] K. Budge and A. Clarke. Academic development is a creative act. *Int. J. Educ. Dev.*, 17:59–70, 2012.

[10] A. Knox. Creativity and learning. *JACE*, 17:96–111, 2011.

[11] C.-Y. Tan, C.-Q. Chuah, S.-T. Lee, and C.-S. Tan. Being creative makes you happier: the positive effect of creativity on subjective well-being. *Int. J. Environ. Res. Public Health*, 18, 2021. Article number 7244.

[12] A. J. Cropley. Creativity and mental health in everyday life. *Creat. Res. J.*, 3:167–178, 1990.

[13] R. A. Beghetto. Creative learning in education. In M. L. Kern and M. L. Wehmeyer, editors, *The Palgrave Handbook of Positive Education*, pages 473–491. Palgrave Macmillan, 2021.

[14] K.-P. Liu, S.-J. D. Tai, and C.-C. Liu. Enhancing language learning through creation: the effect of digital storytelling on student learning motivation and performance in a school English course. *ETR&D*, 66:913–935, 2018.

[15] G. Walton, M. Childs, and G. Jugo. The creation of digital artefacts as a mechanism to engage students in studying literature. *Br. J. Educ. Technol.*, 50:1060–1086, 2019.

[16] M. C.-L. Huang, C.-Y. Chou, Y.-T. Wu, J.-L. Shih, C. Y. C. Yeh, A. C. C. Lao, H. Fong, Y.-F. Lin, and T.-W. Chan. Interest-driven video creation for learning mathematics. *J. Comput. Educ.*, 7:395–433, 2020.

[17] H. Meishar-Tal and A. Kesler. "If I create a game I'll learn": online game creation as a tool to promote learning skills of students with learning difficulties. *Interact. Learn. Environ.*, 31:3071–3082, 2023.

[18] S. Schoen Jr. https://www.scottschoenjr.com/notes. *Georgia Tech Mechanical Engineering Quals Review Book*, 2018.

[19] C. A. Gokani. https://chiragokani.github.io/class/quals/. *Review for the acoustics qualifying exam*, 2023.

[20] M. F. Hamilton. Lecture notes from *Acoustics I* and *II*, two first-year graduate-level courses in acoustics in the Walker Department of Mechanical Engineering at UT Austin, 2021, 2022.

[21] D. T. Blackstock. *Fundamentals of Physical Acoustics*. Wiley, 2000.

[22] R. P. Feynman. *Feynman Lectures on Physics*. California Institute of Technology, 1962. Volume II, Chap. 31.

[23] A. D. Pierce. *Acoustics, 3rd edition*. Springer, 2019.

[24] P. M. Morse and K. U. Ingard. *Theoretical Acoustics*. McGraw-Hill, 1968.

[25] D. V. Schroeder. *An Introduction to Thermal Physics*. Oxford University Press, 2020.

[26] M. R. Haberman. Lecture notes from *Ultrasonics*, a graduate-level courses in the Walker Department of Mechanical Engineering at UT Austin, 2022.

[27] A. Bedford and D. S. Drumheller. *Introduction to Elastic Wave Propagation*. Springer Nature, 2023.

[28] M. F. Hamilton. Lecture notes from *Nonlinear Acoustics*, a graduate-level course in acoustics in the Walker Department of Mechanical Engineering at UT Austin, 2023.

[29] M. F. Hamilton and D. T. Blackstock, editors. *Nonlinear Acoustics, 3rd edition*. Springer, 2024. https://link.springer.com/book/10.1007/978-3-031-58963-8.

[30] M. L. Boas. *Mathematical Methods in the Physical Sciences, 3rd edition*. John Wiley & Sons, 1980.

[31] G. Strang. *An Introduction to Linear Algebra, 5th edition*. Wellesley-Cambridge Press, 2015.

[32] D. J. Griffiths. *Introduction to Quantum Mechanics, 2nd edition*. Pearson, 2015.

[33] D. Rachinskiy. Lecture notes from *Differential Equations*, a sophomore-level undergraduate-level courses in the Department of Mathematics at the University of Texas at Dallas, 2019.

[34] D. J. Griffiths. *Introduction to Electrodynamics, 3rd edition*. Pearson, 1999.

[35] C. A. Gokani, M. R. Haberman, and M. F. Hamilton. Paraxial and ray approximations of acoustic vortex beams. *J. Acoust. Soc. Am.*, 155:2707–2723, 2024.

[36] C. A. Gokani, M. R. Haberman, and M. F. Hamilton. Analytical solutions for acoustic vortex beam radiation from planar and spherically focused circular pistons. *JASA Express Lett.*, 4:1–7, 2024.

[37] P. G. Kaufinger. https://www.youtube.com/@AcousticsDerivations. *Acoustics Derivations*, 2024.

[38] P. G. Kaufinger, J. M. Cormack, K. S. Spratt, and M. F. Hamilton. Perturbation solution for second-harmonic generation in focused shear wave beams in soft solids. *Wave Motion*, 139, 2025. Article Number 103595.

[39] W. T. Wallace. Memory for music: effect of melody on recall of text. *J. Exp. Psychol. Learn. Mem. Cogn.*, 20:1471–1485, 1994.