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Applying Fundamental Soundscape Concepts as a Framework for Introductory Acoustical Engineering and Music Courses*

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In this paper, we propose teaching strategies grounded on an interdisciplinary teaching framework based on the holistic concept of soundscape ecology. The study explores the self-perceived level of understanding engineering and music students exposed to the same foundational course communicated and expressed before and after the course. Results showed that the teaching framework chosen provides a good umbrella for teaching technical, contextual and practical topics. Students seem to grasp better courses related to theory and context than practical activities involving detailed analysis and the use of audio software. Multifaceted topics such as sustainability and interdisciplinary were also difficult to grasp for most students. Compared results for music and engineering showed that, while engineering students showed a substantially more robust background in practical activities related to audio, music students were able to easily reach similar levels of knowledge of these topics by the end of the course. As a way of reducing this gap further, future versions of the proposed course should consider ways of blending engineering and music students in the same classroom environment to foster a greater level of collaboration and interaction among students.

Keywords: soundscape; engineering education; interdisciplinarity; music; creativity; innovation

1. Introduction

The current project aimed to explore the use of teaching tools related to the field of soundscape ecology as a way of introducing students to a variety of social, technical and artistic features in a variety of disciplines related to engineering practice. The study's motivation stems from a former project carried out by the author at Lancaster University in England which explored the use of spatial audio as an interdisciplinary teaching framework in an arts college scenario [1]. As part of this former project music, film, dance, and fine art students were encouraged to engage in interdisciplinary projects using spatial audio as an integral feature of their partnerships. Research results showed that the use of interdisciplinary topics in foundational courses can encourage students with varied academic backgrounds to become more aware of the potential and limitations of their own disciplines while fostering collaborations among students from different academic and social backgrounds. Another study by the author focusing on teaching strategies to enhance employability skills in music technology courses showed similar results. That enquiry showed that an effective way of integrating interdisciplinary topics in a music technology programme is to draw clear links in the syllabus to specific and generic interdisciplinary skills valued by employers in an increasingly diverse and complex professional environment [2] These results concur with recent research that showed that embedding interdisciplinary courses in the early stages of engineering education can provide students with relevant employability skills and an enriched worldview [3]. In the same line, research by Van den Been et al. showed that interdisciplinary teaching strategies in engineering education can be effectively linked with increasing market demands for graduates that can work in teams dealing with multifaceted social and environmental issues [4, p. 7]. Two related recent studies also showed that fostering collaborations between engineering and architecture students in shared teaching environments can be very beneficial for both cohorts, reinforcing communication skills and interest in a wider range of topics outside their expertise and comfort zone [5, 6]. Motivated by these innovative inquiries that underscore the significance of interdisciplinary learning, the research questions of this study were formulated to delve into the limitations and advantages of imparting knowledge on multifaceted subjects that transcend specific disciplines. In this context, the overarching goal was to examine the degree to which theoretical, contextual, and practical aspects of soundscape studies can serve as an effective interdisciplinary foundation for educating emerging engineering and music students. Consequently, the research was designed to address the following three research questions:

1. To what extent do students assimilate disciplinary and interdisciplinary topics at the end of the course? (RQ1)

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2. Do engineering and music students assimilate these topics differently? (RQ2)
3. What features of the course were most valued by students at the end of the semester? (RQ3)

2. Soundscape Ecology as an Interdisciplinary Teaching Tool

Soundscape ecology was established as an interdisciplinary research field by the composer and educator R. Murray Schafer in the seventies and formalised in his influential book *The Tuning of the World* [7]. Concerned by the increasing noise pollution in Canada and other developed countries, Schafer and members of the World Soundscape Project were one of the first researchers to foresee the need for a transdisciplinary understanding of our sonic environment that would consider cultural, technical and also environmental issues [8]. This pioneering approach was inspired by state-of-the-art research in a wide range of disciplines such as acoustics, engineering, music, design, psychology, environmental sciences and urban planning [9]. Soundscape ecology studies since then have developed considerably and expanded into subdisciplines such as acoustic ecology, ecoacoustics, context-based composition, sonification and sound studies [10–12]. As a way of formalising and integrating methodologies from these various trends, a new ISO standard has been developed during the last decade [13]. One of the disciplines identified by Schafer with a great potential for development is music education [14]. Schafer's early pioneering texts focus on the idea of designing an innovative music curriculum integrating artistic, perceptual and technical features of soundscape research. In recent years, there have been few attempts to integrate these topics in a teaching framework that effectively combines creative and technical features of soundscape ecology [15–18]. Inspired by Schafer's innovative educational approach and the results of some of the projects involving music and art students developed at Lancaster University described above, the study presented here aimed to explore the application of this approach in the context of engineering education. A first-year course for two cohorts of students from engineering and music backgrounds was designed and implemented using theoretic, contextual and technical themes related to soundscape ecology.

3. Course Design

3.1 Scope

The rationale behind the course design was to foster a wide-ranging learning framework to introduce a variety of topics related to soundscape ecology for new engineering and music students from Universidad Austral in Valdivia, Chile. For practical reasons, and as a way of creating a basis for later comparisons, lectures and course activities were conducted in separate parallel groups. With this approach in mind, the main challenge of the study was to design and implement a common syllabus for both groups that could be appealing for engineering and music students taking into account curricular demands, as well as dissimilar backgrounds and expectations. The first group involved 34 students enrolled in the BSc Acoustical Engineering degree, a five-year programme with a strong emphasis on maths, physics and projects involving noise measurements and audio production [19]. The second group was comprised of 50 students enrolled at the BA in Music, a four-year humanities degree with an emphasis in music theory and performance [20].

3.2 Structure

The course was divided into three main units. The first unit was conceived considering a conceptual approach with a series of lectures focusing on foundational subjects such as *theory of sound*, *sound perception*, *musical acoustics* and *sound recording*. The lectures were delivered using PowerPoint presentations and a small number of short texts in Spanish and English were considered as the basis for these lectures and given as preparatory weekly readings. The second unit took a more contextual approach and included the following topics: soundscape ecology, sustainability and interdisciplinarity. The focus in this case relied on longer articles in Spanish and English and a series of short written exercises which students were to develop independently using various external sources and the course's available online learning environment [21]. These tasks involved practical exercises analysing by means of various listening techniques audio samples of field recordings carried out by students in various sonic environments in the city of Valdivia [22]. The third and final unit of the course involved a more practical approach and was structured around the design and implementation of a creative music project. The aim of this unit was to encourage students to integrate the conceptual and technical topics previously discussed as a way of developing a creative project involving recording musical instruments and using software audio editing tools. Weekly seminars and workshops were carried out to allow students the opportunity of presenting project audio excerpts by means of loudspeakers and receive constructive feedback from peers and the tutor. As part of this dynamic teaching environment, students were also introduced by a teaching assistant to free audio software analysis and editing tools such as *Sonic Visualiser*

[23] and the digital audio production application *Reaper* [24]. The aim of these seminars was to encourage students to improve their analytical skills by developing a comprehensive technical vocabulary to describe and analyse various kinds of sonic phenomena.

3.3 Learning Outcomes and Assessment

Instruction at Universidad Austral follows a competency-based education model (CBE) that is meant to focus on learning outcomes and authentic performance. The course had two specific and three general learning outcomes. The first specific learning outcome involved "operating professional audio systems by applying relevant professional technical and musical principles". The second one required students "to implement recording projects applying suitable technical and artistic standards". These criteria apply to various courses in both programmes related to music production and artistic features of the courses. The three general learning outcomes were a competent command of the English language, advanced oral and written communication skills and the ability to develop projects as part of a team and a practice disposition towards challenges of a globalised national and international context. These very general cross-cutting outcomes are meant to create a red thread that reinforces strategic competencies inside an academic programme.

The course involved two types of assessment methods related to each of the three units described above. The first one involved a written exam and assessed online exercises. Students were asked to analyse various literary sources and carry out a written test where they had to contextualise and apply various principles related to sound theory, soundscape ecology, hearing and basic recording techniques. The second assessment of the course was a listening workshop in a small auditorium equipped with a professional sound system, where students presented short audio drafts of their music production audio projects for peer feedback. The presentations were followed by an open discussion and detailed feedback by the tutor and between students.

4. Post-pre Survey Results

4.1 Introduction

A post-pre survey method of assessing the goals of the study was designed taking as a starting point the topics of the three units discussed above. As shown in other similar studies, this method provides a simple and straightforward way of assessing the assimilation of specific topics of a curriculum after a course [25, 26]. Anonymous surveys were carried out in 2021, at the beginning and at the end of the 16 weeks duration of the course. The anonymous overall number of participants of the survey at the beginning of the course was 84 and by the end of the course 62 students. This number difference can be explained since many new students dropped out of the course or changed to other engineering programmes during the duration of the semester; 34 engineering and 50 music students took part in the survey at the beginning of the course, while 25 engineering and 37 music students took part in the survey at the end of the semester.

4.2 Perceived Knowledge of the Subjects before and after the Course (RQ1)

In the first part of the survey, students were asked to specify their understanding of the following topics of the course: theory of sound, sound perception, musical acoustics, sound recording, soundscape ecology, sustainability, interdisciplinarity, audio analysis, audio editing and audio mixing. The statement posed in the survey was: "I have a clear understanding of SPECIFIC TOPIC". The survey used a 5-point Likert scale, where the options available were "strongly agree", "agree", "don't know", "disagree" and "strongly disagree". As a way of using a simple and straightforward reporting approach the more significant outcomes of the survey, Summer et al.'s reporting method was used [27]. This method involves adding the number of the responses "agree" and "strongly agreed". These combined results are expressed in percentages in Table 1 and the graph in Fig. 1 shows the overall results of the post-pre survey. As can be observed, there is a considerable difference in the assimilation of the assessed topics before and after the course (49% average). Pre-survey results show low levels of student knowledge on most of the topics presented, with particularly low scores for the topics theory of sound, soundscape ecology, sustainability and audio mixing. While the overall averaged perceived knowledge of theory and context topics before and after the course was similar, it was clearly much lower for practical topics related to audio. Post-survey results show a considerable increase (over 50%) in the perceived knowledge of most topics. The highest scores being in this case for the topics: theory of sound and soundscape ecology. The most assimilated topics ($\geq$ 90%) after the course were those related to sound perception, sound theory, recording and soundscapes. Topics such as interdisciplinarity, sustainability, audio editing and audio mixing were less assimilated by students at the end of the course ($\leq$80%).

4.3 Differences between Engineering and Music Students before and after the Course (RQ2)

Results show that the overall averaged response

Table 1. Post-pre survey results showing the "strongly agree" and "agree" averaged responses for the 83 and 63 survey participants at the start and at the end of the course

TYPE	TOPICS	Pre-score		Post-score		Subject-specific difference	Aggregate Difference
Theory	Theory of sound	24.36	29%	58.90	95%	67%	**53%**
	Sound perception	36.12	43%	55.80	90%	47%	
	Musical acoustics	36.12	43%	53.94	87%	44%	
	Sound recording	35.28	42%	58.28	94%	52%	
Context	Soundscape ecology	12.60	15%	55.80	90%	75%	**56%**
	Sustainability	19.32	23%	45.88	74%	52%	
	Interdisciplinarity	29.40	35%	47.12	76%	41%	
Practical	Audio analysis	47.04	56%	52.70	85%	29%	**36%**
	Audio editing	32.76	39%	42.78	69%	31%	
	Audio mixing	21.84	26%	47.12	76%	49%	
	AVERAGE	**29.48**	**35%**	**51.83**	**84%**	**49%**	

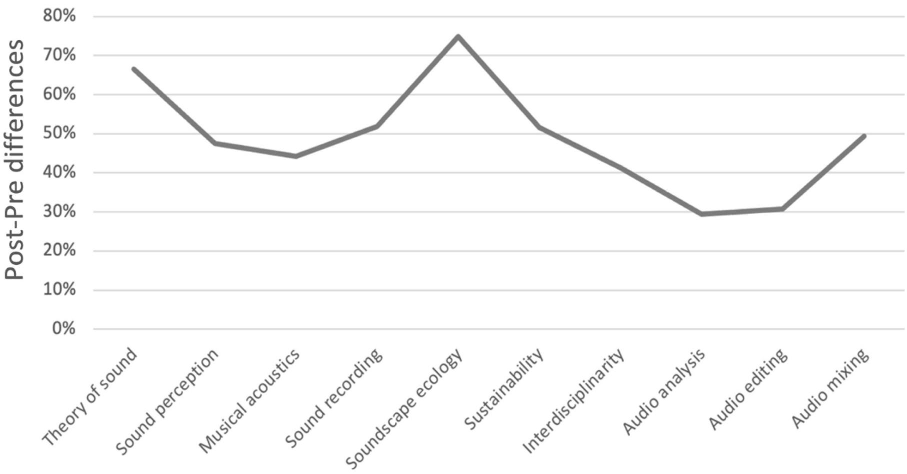

Fig. 1. Global results for the 10 topics assessed in the post-pre survey.

Table 2. Differences between engineering and music students before and after the course

TYPE	TOPICS	Pre-score	Post-score	Difference	Difference
Theory	Theory of sound	1%	1%	0%	**16%**
	Sound perception	27%	10%	17%	
	Musical acoustics	17%	2%	15%	
	Sound recording	34%	4%	30%	
Context	Soundscape ecology	–11%	3%	–14%	**5%**
	Sustainability	6%	–17%	24%	
	Interdisciplinarity	11%	7%	4%	
Practical	Audio analysis	24%	–23%	47%	**47%**
	Audio editing	44%	–2%	46%	
	Audio mixing	34%	–13%	47%	
	AVERAGE	**19%**	**–3%**	**22%**	

differences between Engineering and Music students were larger before (19%) than after the course (–3%). Table 2 shows detailed results of post-pre surveys comparisons between engineering and music students. In line with results shown above, the larger differences between both groups of students at the beginning of the course were for the topics of *sound perception*, *sound recording*, *audio analysis*, *audio editing* and *audio mixing*. Post-survey results show that these differences decreased considerably by the end of the course with several negative values, which could indicate a

Table 3. Main topics mentioned by 62 students in the survey's open question at the end of the course

	Topics mentioned by students	#	Percentage
1	Soundscape	25	40%
2	Microphones	18	29%
3	Project	14	23%
4	Software	13	21%
5	Sound theory	10	16%
6	Hearing	6	10%
7	Feedback	4	6%
8	Interdisciplinarity	2	3%
9	Readings	2	3%
10	Editing	1	2%
11	Mixing	1	2%

Fig. 2. Word cloud results to the open question posed to 62 students at the end of the course.

greater assimilation of specific topics by music students such as *sustainability*, *audio analysis* and *audio mixing*.

While post-pre differences between the two groups of students were relatively small for theoretical and contextual topics (5 and 16%, respectively), results for practical activities of the course involving software audio tools were large (47%). This result could be related to the dissimilar level of knowledge and experience that engineering and music students have with audio software tools prior to the start of the course. Course workshops and seminars showed that engineering students tend to be very familiar with audio software platforms while most music students had little or no prior experience with these tools, needing extra tutoring during the course. Surprisingly, at the end of the course, a considerable number of music students seem to assimilate technical topics more thoroughly than engineering students.

4.4 Open Question (RQ3)

To gauge the overall perspective on the course, students were asked the question, "What were the most interesting aspects of the course?" The responses to this open-ended question are outlined in Table 3, while Fig. 2 visually encapsulates the key themes through a word cloud. Notably, these findings align with the data from Tables 1 and 2, indicating a substantial level of interest in the subject of soundscape among both student groups. The words microphones (sound recording), project and software were also mentioned by a considerable number of students at the end of the course. These findings may indicate an inherent enthusiasm among students for subjects tied to audio equipment and music production projects, aligning with the generally positive outcomes observed in the practical activities detailed in Tables 1 and 2.

Close contact with students during seminars and practical workshops showed that the development of independent creative music production projects as part of the course was considered by students as one of the most original and motivating aspects of the course. The use of the free audio software like *Reaper* and regular tutorials by a teaching assistant were most likely important contributions in this regard. Finally, the very low scores for topics such as interdisciplinarity, audio editing and mixing are slightly surprising. Interdisciplinarity is nowadays a significant topic among academics in research contexts but seems to be a difficult topic to grasp for undergraduate students. As shown in a previous study, this topic needs to be carefully explained and exemplified in various contexts to be effectively integrated as part of a curriculum and aligned with learning outcomes and assessment procedures [1, p. 185].

5. Discussion

The results of the post-pre survey described above provide relevant information and various interesting discussion themes. The substantial overall contrast between pre and post survey scores indicates a significant comprehension and assimilation of the course topics by most students. In the case of theory topics, the post scores are consistently high ($\geq$ 90%), suggesting a possible preference among new undergraduate students for conventional discipline-based subjects, often presented in the traditional classroom style with PowerPoint presentations – akin to the teaching methods commonly found in Chilean high schools. A comparable pattern emerges for contextual topics, albeit with slightly lower scores in the post-assessment, maintaining a similar average for the difference between post and pre-surveys. Notably, post-assessment scores are lowest for sustainability and interdisciplinarity, indicating that these concepts may be less familiar to most students. These findings are in line with findings of a study by Huntzinger et al. that showed that the topic of sustainability seems to be harder to assimilate for new engineering students and should be explained and contextualised in greater detail over a long period of time to be successfully integrated as part of the curriculum [28]. In line with these results, a recent investigation by Mosley showed that the role of sustainability in an audio engineering syllabus is a significant challenge that cannot be ignored [29]. The study argues that recent industry and government policy show that this topic is currently relevant for any professionals working in the field of audio, music or the entertainment sector. A similar argument could be advanced in relation to the topic of interdisciplinarity mentioned above. As shown in various studies, interdisciplinary teaching frameworks are often difficult to effectively integrate as part of an undergraduate curriculum [30, 31]. This seems to be more notorious for new students that have not yet mastered essential disciplinary concepts and key domain-specific knowledge. In line with previous findings by Repko, results of this study showed that the success of an interdisciplinary teaching approach usually resides in a well-crafted balance between disciplinary and interdisciplinary topics in a curriculum design [32]. Repko suggests that this balance should be consistent throughout the duration of the course and reflected in terms of content, assessment, resources and infrastructure.

When comparing the results of the survey for music and engineering students there are some interesting and surprising outcomes. The considerable overall decrease in differences before and after the course between both groups of students is one of the more significant results of this study. This shows that, to some extent, differences in experience and academic background among new engineering and music students are not necessarily a limitation when teaching multi-faceted conceptual themes. A positive implication of this outcome is that, with some minor adjustments and considering the recommendations mentioned above, engineering instructors should be able to design and implement foundational courses that blend undergraduate students from various disciplines without major complications. This accords with results of previous employability research carried out by the author that is mentioned above and which showed that students are most of the time flexible and adaptable when tackling topics related to their professional field [2, p. 235]. The study showed that employers within the audio, live sound and video games industries tend to value candidates' generic skills such as communication, planning, problem solving and teamwork over specific disciplinary skills such as mixing and recording as evaluated in this study. Table 2 shows a considerable difference between theory and context topics in comparison with practical topics where clearly engineering students have considerably more experience than music students. On the one hand, this could be perceived as a limitation in terms of teaching and assessment methods when trying to blend students from music and engineering courses in the same class. On the other hand, this could provide an opportunity for exploring different levels of student collaboration and teamwork to allow engineering and music students to interact freely and benefit from their mutual backgrounds and experience with software and audio hardware tools. Another interesting result shown in Table 2 is that it seems to be easier to introduce interdisciplinary topics early in the engineering curriculum rather than in later courses. Traditional engineering programs in Chile typically provide limited opportunities for early-stage students to explore courses beyond their field. In contrast to this conventional model, the study's results reveal a notable trend: regardless of their academic background, students exhibit similar responses when introduced to interdisciplinary topics early in their university education. This suggests that new students, irrespective of their prior academic focus, display a remarkable openness and eagerness to engage with concepts from diverse disciplines.

The open-ended responses in Table 3 reveal a substantial level of student interest in the soundscape topic, irrespective of their academic backgrounds. In line with results of the study involving the use of spatialised sound mentioned above [1, p. 188], interdisciplinary topics with a wide range of applications provide a suitable framework for tutors to successfully deal with cultural, technical and social issues. In this context it is not surprising that other popular topics among students were software and hardware audio tools used for the development of the music production project of unit 3. As previously mentioned, the inherent attraction of new students to audio and music technology tools can sometimes pose a challenge for educators, as students may lean towards vocational expectations rather than an academic approach to their degree. When looking in detail at the results presented in Table 2 and 3, it is rather surprising to see that this tendency is clearly much more pronounced for music than for engineering students. Contrary to what one might have been inclined to expect, results show that music students tend to value technical topics much more than engineering students. This tendency could be due to the small number of courses related to music technology and audio production that music students are exposed during their education. It may be assumed that music students do not have the basic knowledge or interest in more technical subjects. Results of this study showed that this is not necessarily the case. There is clearly room for development in artistic courses in this respect which could clearly benefit from a more comprehensive and ambitious approach towards technical topics. On the other hand, as shown in a recent study exploring the perceived role of creativity by engineering early-career faculty members, there is clearly a great a potential for fostering nuanced notions of creativity among engineering students [33].

These findings align with the results of a prior study conducted by Rabello-Mestre and the author, demonstrating that the integration of effective feedback and creative methodologies into the engineering curriculum can significantly enhance student motivation and cultivate a dynamic and inclusive learning atmosphere [34]. This positive impact suggests the potential feasibility of integrating engineering and music students within the same educational environment. For practical reasons, in this study, both courses' activities were run separately, with no interaction between groups. Establishing a unified hybrid collaborative learning environment, facilitating student interactions, opens the door to exploring more diverse and ambitious teaching strategies. This approach could enable students to leverage each other's disciplinary backgrounds and expertise with software and hardware tools. Moreover, this model could serve as a blueprint for fostering cross-faculty teaching collaborations, extending beyond engineering to include architecture, design, and fine arts degrees.

6. Conclusions

The idea of teaching an interdisciplinary course involving topics related to soundscape ecology highlighted opportunities for innovative teaching strategies as well as challenges involving students' expectations and preconceptions of disciplinary boundaries. In accordance with the findings of previous studies, the results of the research presented in this article indicate that the incorporation of interdisciplinary teaching topics, particularly those related to soundscape studies, provides new undergraduate engineering and music students with a comprehensive understanding of their disciplines in connection to other professions. This approach effectively blurs the traditional boundaries between Science and Humanities courses. The study also revealed that the proposed integrated learning framework successfully narrowed the knowledge and experience gap among students prior to the course. Future versions of the course could consider the possibility of blending students from both degrees in a single learning environment as a way of minimising this gap. It could be anticipated that this blended design would potentialise peer-assessment strategies further, allowing students to learn from each's other experience and knowledge. Creativity and innovation topics could provide the key to materialise this integration, improving students' motivation and an inclusive learning ethos.

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