FACULTY OF EDUCATION
DEPARTMENT OF PEDAGOGICAL CURRICULAR AND PROFESSIONAL STUDIES

FLYING UNDER THE RADAR?

EDUCATION FOR SUSTAINABLE DEVELOPMENT IN PRIVATE PILOT TRAINING

Michael Stiebe

Master's thesis:	30 credits
Programme/course:	S2ESD ESD700
Level:	Second cycle
Term/year:	Spring 2023
Supervisor:	Aimee Lee Haley
Co-Supervisor	Magdalena Svanström
Examiner:	Hanan Innabi

Abstract

Master's thesis:	30 credits
Programme/Course:	S2ESD ESD700
Level:	Second cycle
Term/year:	Spring 2023
Supervisor:	Aimee Lee Haley
Co-Supervisor	Magdalena Svanström
Examiner:	Hanan Innabi
Keywords:	Private Pilot Training, Sustainable Aviation, General Aviation, Transformative Learning, Education for Sustainable Development

Aim: Private pilot (PPL(A)) training has hardly received any scholarly attention from educational and sustainability science perspectives. Through an Education for Sustainable Development (ESD) perspective, the study aimed at 1) answering how sustainability and sustainable development (SD) are taught in pertinent PPL(A) theory learning material, theory lessons and practical training, 2) identifying gaps pertaining to sustainability and SD in those three components, and lastly 3) explore if and how certificated flight instructors, theory instructors and student pilots experience transformative learning during PPL(A) training, as well as what possibilities these stakeholders see in supporting transformative learning in PPL(A) training.

Theory: This study was framed in the research paradigm of pragmatism. The theoretical lens through which the research problem was investigated was on a general level ESD. Within the context of ESD, the research used the perspective of Mezirowian Transformative Learning Theory.

Method: Focusing on Switzerland, this multi-methods study combined secondary and empirical methods. Firstly, a thematic document analysis (following Braun and Clarke) was applied to the two main PPL(A) learning materials. Secondly, semi-structured interviews with three certificated flight instructors (CFIs), one current student pilot, and two recently certificated private pilots were conducted. The interview analysis was conducted analogously to the document analysis. The results from both analyses were triangulated to answer the research questions.

Results: The study found that sustainability and SD were not adequately addressed in PPL(A) learning material and theory lessons, and only slightly more in practical training. This highlights the need to include sustainability and SD in all aspects of PPL(A) training, including the practical training syllabus to induce disorienting dilemmas in students. The study also suggests transforming the role of the CFI to become an educator that serves as a *facilitator* and *provocateur* in the Mezirowian sense of transformative learning. Applying a transformative ESD approach has the potential to catalyze sustainability in PPL(A) training, GA, and even the commercial aviation sector due to potential spillover effects.

Foreword

Over the course of my life and academic career, sustainability and sustainable development have become increasingly important themes sparking both personal dilemmas as well as a growing thirst for investigating related issues through academic research, especially in the multi-faceted fields of transport and mobility.

To conduct research and generate knowledge is one side of the coin, to teach and facilitate meaningful learning experiences in people the other. Teaching piano during my high school years and tutoring high school students marked the early beginnings of my journey of trying to become an educator. This journey continued when I started teaching students on sustainable mobility in university a few years ago. Along with becoming increasingly aware of the challenges in teaching and the teacher – learner relationship, I have developed a growing interest in the mechanisms that coin education experiences.

One of the most fascinating forms of human mobility is aviation. In late 2020, I started my journey of becoming a private pilot, which I successfully concluded in 2022. What inspired me to do this? In retrospect, it was probably a combination of my deeply rooted childhood dream of flying an airplane myself as well as the Covid-19 pandemic that suddenly cut deep wounds into my personal travel freedoms. While sustainable aviation has long been a prominent theme in commercial aviation, I quickly noticed during my active time as student pilot that sustainability was not nearly as often on the radar in private pilot training and General Aviation, and (nearly) absent in academic research.

To make a first step in academia, I conducted my 2022 study *Come Fly with Me (Sustainably): Pathways to Sustainable General Aviation and Private Pilot Training* that served as an inspiration for this thesis. The specificity and complexity of the research problem in this thesis required me to provide a bit more background information to frame the context, which eventually led to a slight exceedance of the word limit.

I want to express my deepest gratitude to the teachers in the ESD program at the University of Gothenburg who taught and provided me with diverse perspectives in this important field of education. I want to give my heartfelt thanks to my supervisor and my co-supervisor who guided me and gave me valuable critique during the research process which improved the overall quality of this thesis. Lastly, I want to thank all my interviewees for having taken their time and for providing me with important insights that helped produce genuine empirical research results.

Table of Contents

Table of Figures

List of Abbreviations

Abbreviation	Definition
AVGAS	Aviation Gasoline
AVGAS 100LL	Aviation Gasoline 100 Octane Low Lead
CAA	Civil Aviation Authority (e.g., FAA, EASA, FOCA, etc.)
CFI	Certificated Flight Instructor
DLR	Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Center)
EASA	European Union Aviation Safety Agency
EDB	Ethylene Dibromide (Scavenger Chemical in leaded AVGAS)
EET	Estimated Elapsed Time = The estimated time required to proceed from one significant point to another (ICAO definition)
FAA	Federal Aviation Administration (USA)
FI	Flight Instructor, e.g., FI(A) = Flight Instructor for Airplanes
FL	Flight Level (e.g., FL110 = altitude 11,000 feet)
FOCA	Federal Office of Civil Aviation (Switzerland)
GA	General Aviation
GHG	Greenhouse Gases, e.g., carbon dioxide
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
LAPL(A)	Light Aircraft Pilot License (only EASA territory)
MTOW	Maximum Take-Off Weight
PPL(A)	Private Pilot License (Airplane)
SEP	Single Engine Piston
STC	Supplemental Type Certificate
TEL	Tetraethyl Lead (Antiknock Agent in Leaded Gasoline)
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions

1. Introduction

The human desire to fly dates back thousands of years, with stories and legends from ancient civilizations and mythologies depicting attempts to soar through the skies like birds. It was not until the late 19th century, however, that human flight became a reality. The Wright Brothers are often credited with inventing the first successful airplane, which flew for 12 seconds in 1903 (Lukasch, 2003). Since then, aviation has rapidly evolved and transformed the way we travel and transport goods. Today, airplanes, helicopters, and other aircraft are used for a variety of purposes, from commercial passenger transport to military operations to scientific research and even private aviation for pure leisure.

Aviation is divided into three sectors: Commercial Aviation, Military Aviation, and General Aviation (GA). Recent phenomena such as flight shame (from Swedish: *flygskam*) and the Covid-19-related downturn of air travel have sparked societal, political and academic debates about potential pathways to manage the transition towards sustainability.

While concerns about sustainability in the commercial aviation sector have grown substantially over the last few years, GA has received only very little societal and scholarly attention in this regard and has mostly flown under the sustainability radar. However, GA is the largest aviation sector in terms of registered aircraft, aircraft movements, flight hours, and active pilots. The International Civil Aviation Organization (ICAO) defines GA as "all civil aviation operations other than scheduled air services and non-scheduled air transport operations for remuneration or hire" (SKYbrary, 2023). GA plays a central role in aviation and can be considered its cradle since it is the sector to which pilot training belongs, along with a plethora of other activities (e.g., private aviation, business aviation, search and rescue, medical emergency flights, etc.). The first step in almost all pilot careers is the obtainment of a private pilot license (PPL), regardless of whether they stay private pilots, or become commercial or airline pilots.

Although EASA (2022) acknowledged that pilot training is an important area that can contribute to overcoming the environmental challenges, the sustainability transition in pilot training is still in its early stages. Hitherto, this issue has received almost no attention in academia and there is still no academic consensus on how to define sustainable aviation.

While sustainability and sustainable development have not been extensively studied in the context of General Aviation (GA), particularly in relation to Private Pilot License (PPL(A)) training, the existing academic literature on this subject is limited. However, there are a few exceptions. For example, Edwards and Parker (2022) and Stiebe (2022) have incorporated stakeholder perspectives on

sustainability in GA and PPL(A) training, while Leuenberger and Lutte (2022) have examined gender-related issues in PPL(A) training. Most published papers focus on engineering, environmental, or safety perspectives, without considering educational science or Education for Sustainable Development.

To the author's best knowledge, this thesis is the first academic study to investigate PPL(A[1]) training from the perspective of Education for Sustainable Development.

1.1. Research Aim and Questions

Through the lens of Education for Sustainable Development (ESD) and Mezirowian Transformative Learning Theory, this research seeks to contribute to the academic understanding of the roles of sustainability and sustainable development within the under-researched educational process of private pilot training for airplanes (PPL(A)). The geographical focus of this empirical study was laid on Switzerland. The country was chosen as a case for several reasons, namely 1) Switzerland is a small but very diverse country with a lively and innovative General Aviation community, 2) Switzerland is a leading country concerning research and development of technologies for sustainable aviation, 3) the author has conducted previous related research on sustainability in Swiss GA (Stiebe, 2022), and 4) the author is an active private pilot in Switzerland which provided him with favorable access to the research field which is especially important when it comes to the recruitment of interviewees. The thesis is guided by the following research questions:

RQ1: What is taught about sustainability and sustainable development in private pilot license learning material, theory lessons, and practical private pilot training in Switzerland? What gaps exist?

RQ2: How do certificated flight instructors, theory instructors and student pilots experience transformative learning in private pilot training? What possibilities do they see in supporting transformative learning in private pilot training?

[1]Airplane

1.2. Thesis Outline

The thesis consists of eight chapters. Chapter 1 introduces the topic, problem, research gap, and research questions. Chapter 2 provides context, while Chapter 3 reviews previous academic research. Chapter 4 presents the theoretical framework, and Chapter 5 details the methodology, including ethical considerations and limitations. Chapter 6 presents the research results and answers to the research questions. Chapter 7 critically discusses the results within the theoretical framework. Finally, Chapter 8 summarizes the key results and conclusions, and makes recommendations for future research.

2. Background

This chapter outlines information that is vital to understanding the context of this thesis.

2.1. Sustainability and Sustainable Development

Sustainability and sustainable development (SD) have become a part of every-day vocabulary. Inflationary use of these terms, especially in product and service marketing, as well as a paradoxical plethora of definitional approaches have led to "fuzziness" concerning the meaning of sustainability and SD (Dimitrov, 2010). In an age where almost everyone thinks they know what sustainability means, defining sustainability and SD and reminding ourselves of its roots have become ever-more important.

2.1.1. Definitions and Models of Sustainability and Sustainable Development

Today, sustainability and SD are often defined by referring to the original 1987 Brundtland Commission definition considering SD to be "development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs" (WCED, 1987).

Although alternative theoretical models such as the five-dimensional sustainability model proposed by Seghezzo (2009) (see *Figure 2*) exist, sustainability and sustainable development are in most contexts associated with a three-dimensional "Triple-Bottom-Line" (TBL) model established by Elkington (1997). The TBL acknowledges the three dimensions or "Ps", (1) People, (2) Planet, (3) Prosperity which are often translated into three pillars, i.e. (1) Social, (2) Environmental, and (3) Economic. Despite a plethora of definitions, those based on a three-pillar principle are clearly dominating in quantitative terms (Waseem & Kota, 2017) (see *Figure 1*).

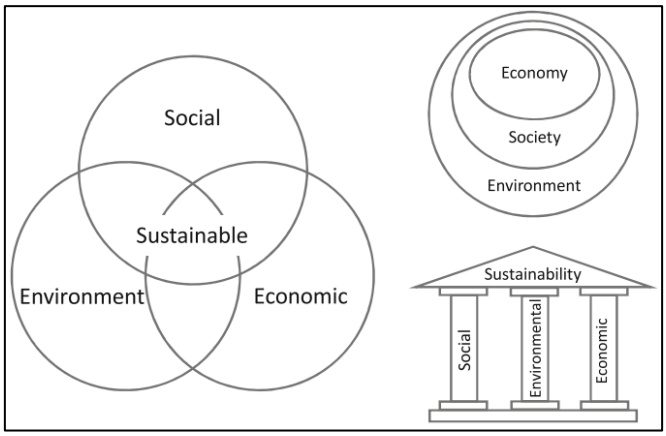


Figure 1: Common Representations of Sustainability as Three-Pillar/Three-Dimensional Models (Intersecting Circles, Left; Nested Triple-Bottom-Line, Upper-Right Corner; Literal Pillars, Bottom-Right Corner), from Purvis et al. (2019, p. 682)

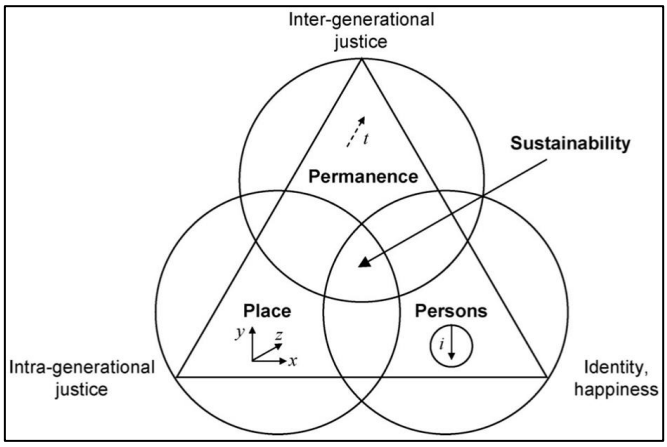


Figure 2: Five-Dimensional Sustainability Triangle Model, Place: Three Dimensions of Space (x, y, and z); Permanence: Fourth Dimension of Time (t); Persons: Fifth, Human Dimension (i). adopted from Seghezzo (2009, p. 548)

2.1.1.1. Critique on Common Sustainability Conceptualizations and Definitions

Voices critiquing current sustainability and sustainable development definitions have become louder throughout the last two decades. While sustainability is widely recognized as a critical goal for individuals, businesses, and governments, there are several critiques of the common conceptualizations of sustainability. Some of the prominent critiques include:

1. **Oversimplification:** Many oversimplify the concept, reducing it often to environmental concerns only, without taking into account the economic and social dimensions. See for instance, Barkemeyer et al. (2014); Dymitrow and Halfacree (2018)

2. **Ambiguity:** Sustainability conceptualizations often lack specificity and are vague in terms of how they can be achieved or measured. This is addressed, for instance, in Parris and Kates (2003)

3. **Lack of Clear Time Horizons:** Many conceptualizations focus on the present and either do not consider the long-term implications of actions and decisions for future generations or are vague in defining their time horizons as for example addressed in Banerjee (2012)

4. **Disregard for Social Sustainability:** Often, academic scholars and other stakeholders fail to consider the social dimension of sustainability in their research and actions, leading to the perpetuation of social inequalities and the exploitation of vulnerable populations. Boyer et al. (2016, p. 2), for instance, argue that "(..) the social pillar remains marginalized by a sustainability agenda that is historically rooted in specific forms of environmentalism based in models of global capitalism that thrive upon the exploitation of natural and human capital".

5. **Focus on Growth:** Many definitions prioritize economic growth or prosperity over the other dimensions of sustainability, leading to an unsustainable use of natural resources and perpetuating environmental degradation.

6. **Anthropocentric Focus/Bias:** Often, sustainability and sustainable development conceptualizations prioritize human interests over the well-being of other species and ecosystems. Nature is often viewed as a resource to be exploited for human benefit, rather than considering the intrinsic value of it. This perspective has led to the depletion of natural resources and the degradation of ecosystems, which ultimately affects human well-being in the long run. Moreover, an anthropocentric approach to sustainability often fails to take into account the interdependence between humans and the natural world. This anthropocentric bias is a frequent problem in Education for Sustainability (Kopnina, 2014). Human well-being is intricately linked to the health and resilience of ecosystems, and neglecting this connection can have devastating consequences. For instance, climate change, which is largely caused by human activity, has profound impacts on biodiversity, ecosystem services, and human societies. An alternative to an anthropocentric approach is an *ecocentric perspective*, and in the case of education, *ecopedagogy*, which place equal value on all species and ecosystems and recognizes the inherent interdependence and interconnectedness of all living beings (Kahn, 2010; Kopnina et al., 2018). An ecocentric approach recognizes that human wellbeing cannot be achieved without a healthy and thriving natural world. Therefore, prioritizing ecocentrism over anthropocentrism may be more likely to foster long-term sustainability and well-being for all living beings in the biosphere.

This list is not exhaustive but proves how important it is important to recognize that sustainability is a complex and multi-dimensional concept which requires a nuanced understanding and a holistic approach to its facilitation. The complexity of sustainability qualifies it as a *wicked problem* (Murphy, 2012).

2.1.2. Goals and Targets in Sustainable Development

Since the publication of *Our Common Future*, the United Nations (UN) has become a key stakeholder in promoting SD (Imber, 1993). In 2000, the UN established the Millennium Development Goals (MDGs) (see *Figure 3*) to reduce poverty and improve global well-being by 2015 (McArthur, 2014). While progress was made, significant challenges remained, leading to the establishment of the more comprehensive Sustainable Development Goals (SDGs) in 2015. The universally adopted (all UN member states) SDGs comprise 17 goals (see *Figure 4*) and 169 targets aimed at ending poverty, protecting the planet, and ensuring peace and prosperity for all (Bali Swain & Yang-Wallentin, 2020).

Figure 3: United Nations Millennium Development Goals (MDGs), from GAVI (2022)

Figure 4: United Nations Sustainable Development Goals (SDGs), adopted from myclimate (2023)

2.2. Aviation

The aviation industry is divided into three sectors: Commercial Aviation, General Aviation (GA), and Military Aviation. This research focuses on GA.

2.2.1. General Aviation (GA)

The International Civil Aviation Organization (ICAO) defines GA as "all civil aviation operations other than scheduled air services and non-scheduled air transport operations for remuneration or hire" (SKYbrary, 2023).

GA is often confused with or understood as "aviation in general" and shows a tendency of sparking mental images of recreational flying activities on small single-engine piston airplanes at small (rural) airfields. While this only applies to approximately 25% of GA, the other 75% of the approximately 40 million annual GA flight hours worldwide are generated by activities such as pilot training, business aviation, agriculture including crop spraying, emergency medical services, civil search and rescue, among others (IAOPA Europe, 2023; SKYbrary, 2023). A typological overview can be found in *Appendix 1: Typological Overview of General Aviation (GA)*.

Although the spectrum of aircraft used in GA is very broad and ranges from business jets to ultralight two-seater aircraft, NASA made an attempt to characterize the *typical* GA aircraft in the late 1990s based on the U.S. GA population and concluded "(..) the typical General Aviation aircraft is four-place, single engine piston all-aluminum aircraft with a fixed tricycle landing gear and a cable-operated flight control system" (Turnbull, 1999, p. 19).

According to Haygood (2021), there are 1.5 to 2.3 million active pilots worldwide (GA, commercial, airline, and military). There are an estimated 350,000 aircraft and 700,000 pilots involved in GA worldwide, which is much compared to only 60,000 aircraft and 400,000 pilots in commercial air transport (including charter and cargo) (IAOPA Europe, 2022). The largest player in GA is the USA (Haygood, 2021). Even though GA is the largest aviation sector in terms of aircraft movements, registered aircraft, and active pilots, it is the smallest in terms of aviation fuel consumption accounting for only 4% of total aviation fuel as can be seen in *Figure 6* (Gössling & Humpe, 2020).

Figure 5: A range of GA Aircraft parked at Lausanne Aerodrome LSGL, Switzerland, Image Source: Author

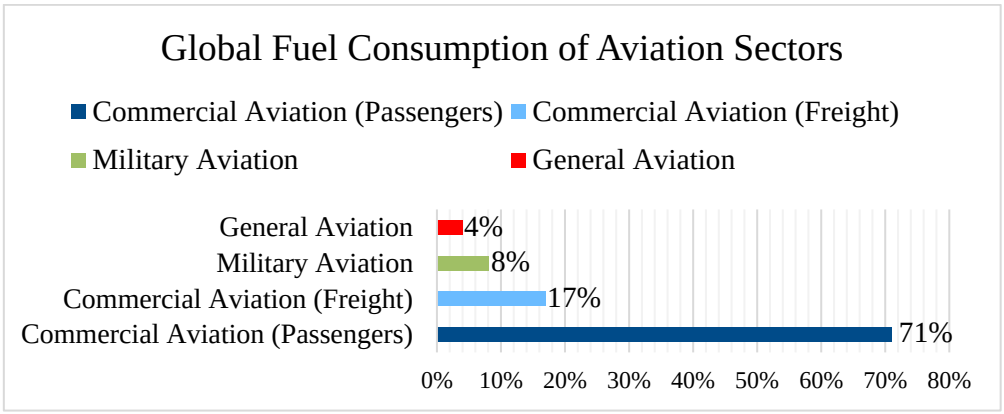


Figure 6: Global Aviation Fuel Consumption by Aviation Sector, based on Gössling and Humpe (2020)

During the pandemic, commercial freight transport and GA sectors saw growth despite the decline in air travel. GA initially suffered from reduced activity, but private aviation gained popularity as a safer alternative to commercial air travel. The pandemic also accelerated the adoption of new technologies in GA, such as virtual flight training and theory distance learning as people looked for ways to continue their aviation education while complying with social distancing guidelines (Hwang & Choi, 2022). These trends, along with teleworking, increased free time, and higher disposable income, have contributed to an increase in PPL(A) student pilots. A U.S.-focused study found a 23% increase in private aviation CO_2 emissions due to the pandemic-induced boom in private aviation, increasing private aviation's share in total aviation emissions (Sobieralski & Mumbower, 2022).

2.2.1.1. General Aviation in Switzerland

Switzerland's GA history dates back to the early days of aviation. Swiss pioneers, such as Oskar Bider and Alfred Comte, contributed to the development of GA nationally and internationally (Jäger, 1950; Tagesanzeiger, 2010). Swiss pilots set records, including the first flight across the North Pole (Marsh, 1926), and played a role in the country's defense during WWII (Kreis, 2016).

Many of Switzerland's GA airfields have roots in the WWII period. Today, Switzerland's GA industry comprises many flying clubs, private pilots, aircraft owners, experimental aircraft builders, researchers, and commercial stakeholders like Pilatus Aircraft. In 2021, GA accounted for 84% of the roughly 1.2 million civil aviation aircraft movements in Switzerland (see *Figure 7*), and there were 1,436 registered small GA motor airplanes (FOCA, 2023).

Five years ago, Schlittler (2018) argued that the booming days of GA Switzerland are counted, which would reflect in a major drop in PPL holders over the first two decades of the 21st century. While recent statistical trends may underpin this (see *Figure 8* and *Figure 9*), it is uncertain whether there will not be a trend reversal, especially, with potentially lower costs and more attractive environmental images of GA due to the increasing market penetration of electric airplanes, such as the Pipistrel Velis Electro.

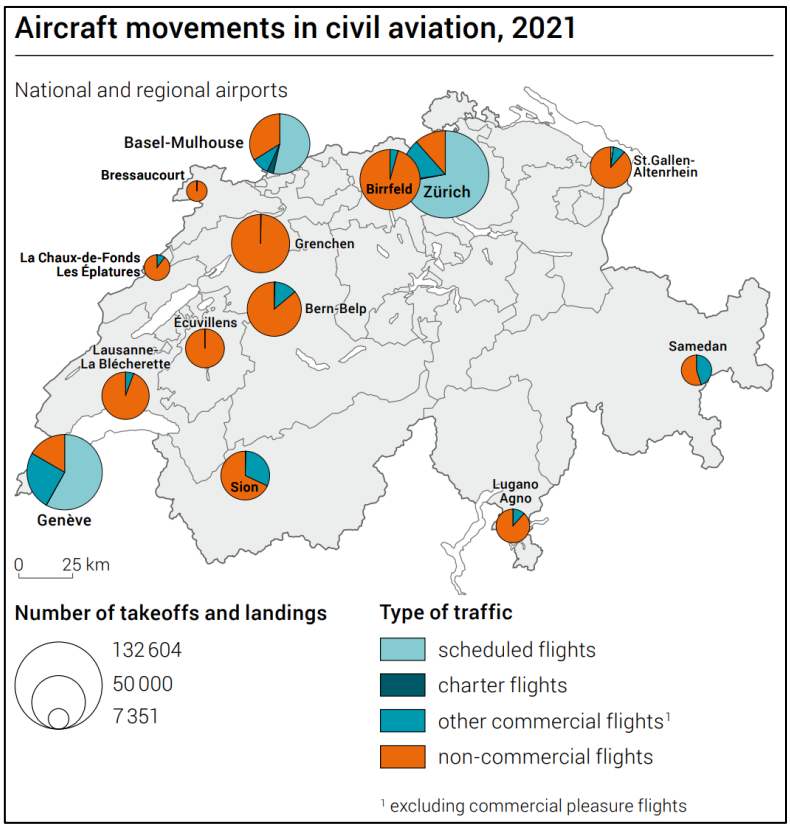


Figure 7: Aircraft Movements in Civil Aviation in Switzerland, 2021, adopted from FOCA (2022c, p. 13)

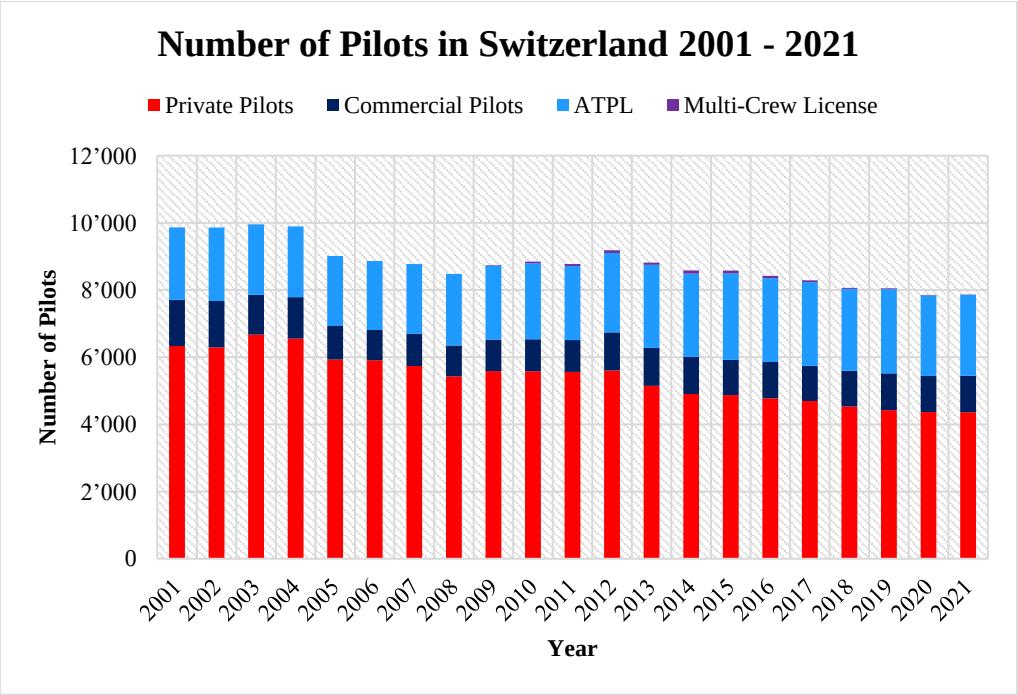


Figure 8: Number of Certificated Pilots in Switzerland by License Types from 2001 to 2021, Federal Statistical Office (2022)

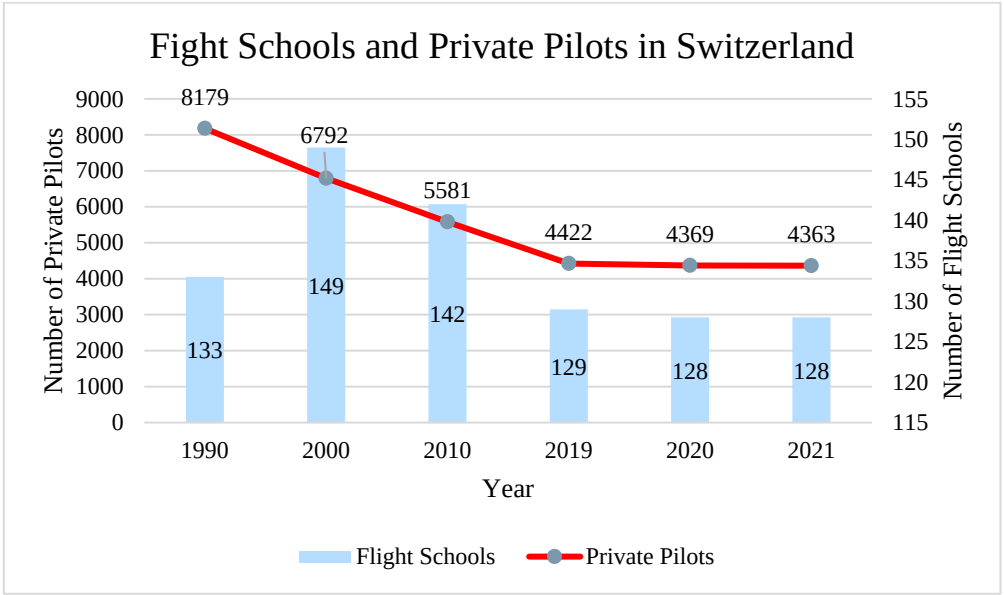


Figure 9: Number of Flight Schools and Private Pilots in Switzerland from 1990 to 2021, based on FOCA (2023)

2.2.1.2. Private Pilot Training

The Wright Brothers conducted the world's first flight training in France between 1908 and 1909, and in 1910, they established the first fully civilian flight school in Montgomery, Alabama (Ennels, 2002; Parks, 2015). Today, there are thousands of flight schools all over the world, including 128 in Switzerland (FOCA, 2023).

Most types of pilot licences are widely standardized in accordance with ICAO guidelines with some exceptions and local differences specified by other national or supranational civil aviation authorities (CAA), such as EASA and FAA. There are four main types of pilot licenses, i.e. (1) *Private Pilot License* (PPL), (2) *Commercial Pilot License* (CPL), (3) *Airline Transport Pilot License* (ATPL), and (4) *Multi-Crew Pilot License* (MPL). *Figure 10* shows the different licenses and how privileges are gradually acquired in pilot training.

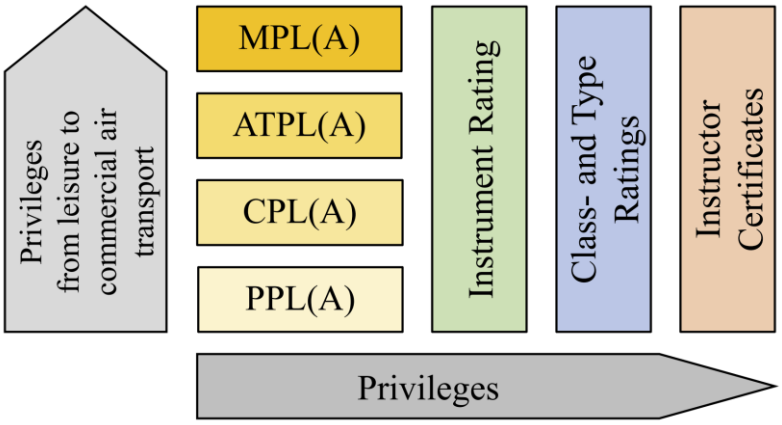


Figure 10: Schematic Overview of Pilot Training, adopted from Schaffernak et al. (2020, p. 5)

In order to become a certificated private pilot, the obtainment of a Private Pilot License (PPL) (United States: Private Pilot Certificate) is essential. In certain regions of the world, e.g., the U.S. or Europe, there exist some comparable license types that, however, come with reduced privileges. In the EASA-territory, there is the (EASA-exclusive) LAPL (Light Aircraft Pilot License) that cannot be used in non-EASA countries nor can an instrument rating[2] be acquired (European Commission, 2022). Both license types permit the non-commercial transport of passengers (PPL: as many as the aircraft legally permits;

[2] The pilot is only allowed to operate aircraft under *Visual Meteorological Conditions* (VMC).

LAPL: max. 4 people on board incl. pilot) (FlyGA, 2022). In the U.S., there is the Recreational Pilot Certificate whose usage is also geographically limited.

Summary of Basic Requirements and Components of PPL(A) Training according to EASA-Part-FCL[3]

- Minimum age of 16 (license issued earliest at 17)
- Hold a Pilot Medical Certificate Class 2
- Achieve a minimum ICAO English Language Proficiency Level 4
- Pass a Radiotelephony Examination
- Complete 100 hours of theoretical training (35 with instructors in a classroom) and pass exams in 9 subjects:
    - Air Law
    - Aircraft General Knowledge
    - Flight Performance and Planning
    - Human Performance and Limitations
    - Meteorology
    - Navigation
    - Operational Procedures
    - Principles of Flight
    - Communications
- Complete a minimum of 45 flight hours, including 10 hours of solo flight (including a 150 NM/270 km cross country flight with two full stops at different airfields)
- Pass a practical test ("checkride") with a CAA-authorized examiner.

2.2.2. Sustainable Aviation

In the late 1990s, debates about sustainable aviation arose after the publication of the IPCC Special Report on the climate change impacts of aviation (Penner et al., 1999; Walker & Cook, 2009). The topic has since attracted increasing attention from stakeholders. However, despite the aviation community's consensus on the need for sustainability, there is no agreed definition (Franz et al., 2013). A systematic

[3] See https://www.easa.europa.eu/sites/default/files/dfu/Part-FCL.pdf, accessed May 14, 2023

review by Afonso et al. (2023) identifies five key aspects of sustainable aviation: aerodynamics, propulsion, energy, materials, and structures (see *Figure 11*).

The University of Michigan Aerospace Engineering Department regards sustainable aviation as a multi-disciplinary field that seeks solutions to improve the environmental and societal impacts of air transportation that aims to reduce aviation's contribution to climate change through new practices and radical innovation (University of Michigan, 2023).

Olawuyi (2016) sees sustainable aviation as a pathway for promoting efficiency within the aviation sector, while reducing the emission of greenhouse gases from aircraft and other aviation facilities while emphasizing the importance of cleaner and energy-efficient aircraft, improved facilities for air traffic control and management, and alternative/renewable fuel options**.**

NASA (2022) also has a focus on sustainable aviation and provides a definition, though not explicit one, and argues that aviation needs to be sustainable so the environment can be protected, the economy can grow, and people can continue to connect in person quickly across long distances thanks to the marvel of air travel.

Based on the aforementioned definitions and descriptions of sustainable aviation, this thesis defines:

> *Sustainable Aviation is a pathway entailing social, technological, economic and political measures as well as research activities that contribute to a holistic transformation of activities that involve the operation of heavier-than-air aircraft in such a way that they do not accelerate global warming, harm the Earth's biosphere nor hinder global economic prosperity and human connectivity.*

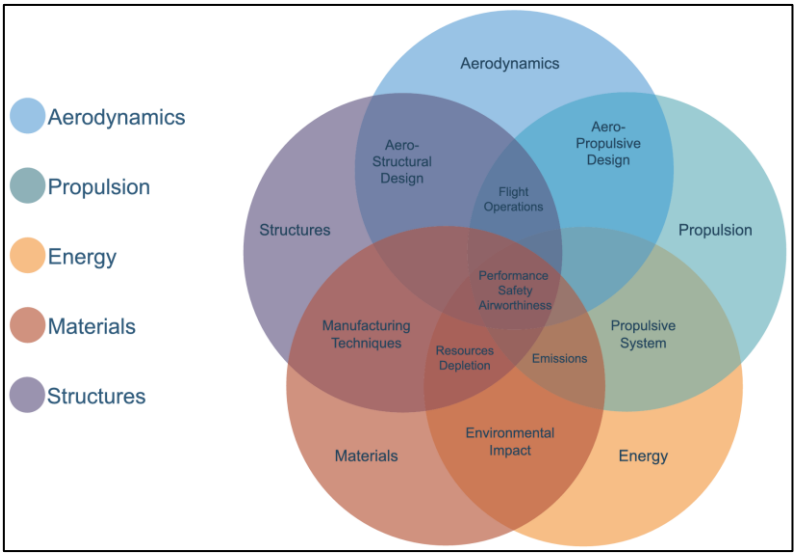


Figure 11. Key Aspects of Sustainable Aviation, adopted from Afonso et al. (2023, p. 4)

2.2.2.1. Sustainable Aviation's Relation to Sustainable Development Goals

Sustainable aviation relates to several UN SDGs, particularly SDG 13 (Climate Action) due to aviation's significant contribution to greenhouse gas emissions. Sustainable aviation can also contribute to SDG 4 (Quality Education) by providing better access to flight training and incorporating SD. Additionally, sustainable aviation can increase gender equality in the aviation industry (SDG 5), reduce the carbon footprint of the aviation industry (SDG 7), promote innovation and infrastructure development (SDG 9), provide access to remote regions and support economic development (SDG 11), promote responsible consumption (SDG 12), and reduce the impact of aviation on marine and coastal ecosystems (SDG 14). See for instance Dimitriou and Sartzetaki (2020); Leuenberger and Lutte (2022).

While GA has a relatively small carbon footprint compared to commercial aviation, it is still strongly connected to SDG 13. Societal and political pressure in many countries puts GA under the category of an environmentally unfriendly and noise-polluting hobby, endangering its existence. Therefore, GA "should be at the forefront to propose alternatives in terms of CO_2 reduction and noise reduction" (Stiebe, 2022, p. 28) to signal a strong willingness to facilitate a sustainability transition.

2.2.2.1.1. <u>Sustainability Challenges in GA</u>

This section outlines a range of pertinent sustainability challenges in GA.

Climate Change and Global Warming Impacts

Aviation has a significant impact on climate change, not only through direct CO_2 emissions but also non-CO_2 emissions, e.g., nitrous oxides (NO_x), sulphur oxides (SO_x), water vapor, soot, and contrail-related cirrus clouds (Scheelhaase et al., 2015). However, the impact of non-CO_2 emissions is not critical for GA since most GA activities are conducted at lower altitudes than commercial aviation (Pilot Institute, 2021). The available data on GA's climate impact is sparse, with estimates ranging from less than one percent to about two percent of total aviation CO_2 (AOPA, 2008; FOCA, 2007; Graver et al., 2019). There are significant optimization potentials in GA, considering the old technologies and designs used in GA aircraft, which are on average 50 years old (Luebbers, 2019).

Noise Pollution

Noise pollution touches upon the social pillar of sustainability, and is a substantial environmental problem and hot topic in aviation, especially in densely populated countries like Switzerland (FOCA, 2022b; Homola et al., 2019; Sobotta et al., 2007). Noise abatement is a priority for aviation stakeholders (FOCA, 2022b; Min et al., 2015), but legal noise levels and mitigation measures vary by country. Pilots, student pilots, flight instructors and airfield staff are frequently exposed to significant levels of noise stemming from airplane engines. Studies show that there is a significant correlation between flight hours, level of noise exposure time and increased hearing loss risks (Antuñano & Spanyers, 2006; Atalay et al., 2015; Beringer & Harris Jr, 2005; Nie et al., 1997).

Health Impacts from Lead and Bromide Emissions from AVGAS 100LL

Leaded fuel, particularly AVGAS 100LL, is still used in GA due to its ability to increase fuel octane and prevent engine knocking. However, AVGAS 100LL is the only remaining fuel that contains tetraethyl lead (TEL) and thus generates a large share of the atmospheric lead and bromide emissions (from scavenger *ethylene dibromide* EDB). These emissions are adverse to human health (e.g., nervous system, body development, reproduction, etc.) (Angrand et al., 2022; FOCA, 2007; Kumar et al., 2018; Levin et al., 2021; Zahran et al., 2017). The FAA plans to phase out AVGAS 100LL by 2030, and the European Chemicals Agency has added TEL to its authorization list, which may result in a de facto phaseout of AVGAS 100LL in Europe by 2025 ECHA, 2022). Two-thirds of the Swiss GA community consider the continued use of AVGAS 100LL to be a key sustainability issue (Stiebe, 2022).

Gender-Related Issues

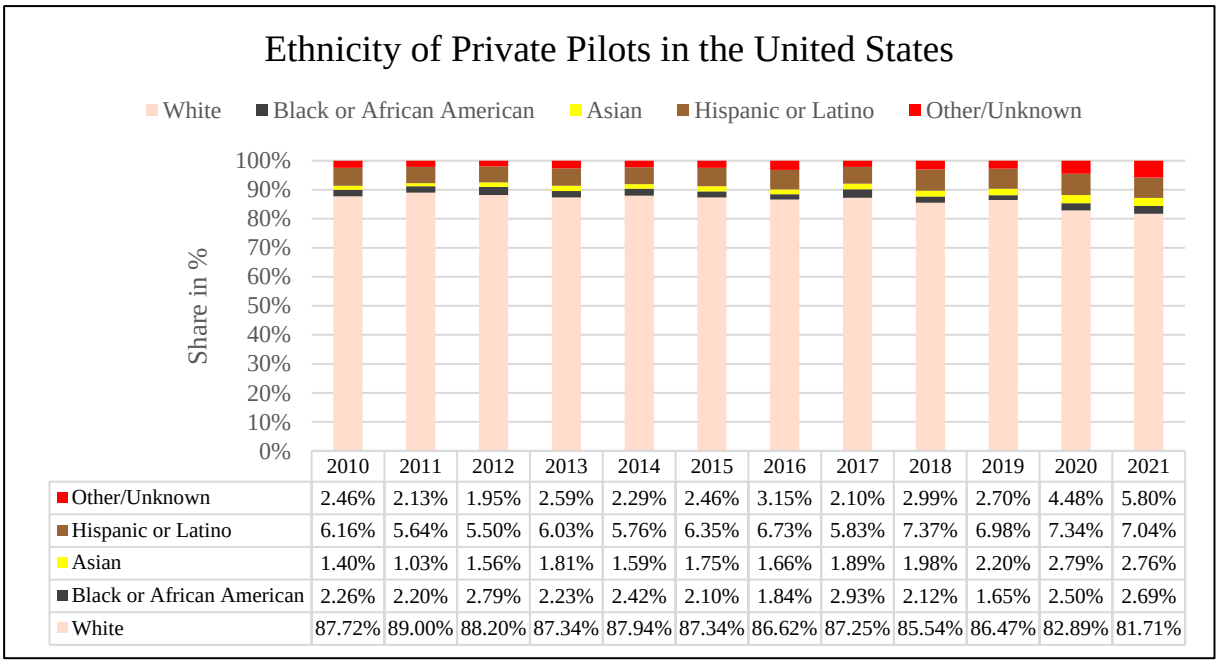
The popular image of aviation being a male-dominated industry are confirmed and reflected in pertinent statistics (Bazargan & Guzhva, 2011; Leuenberger & Lutte, 2022; Mitchell et al., 2005). More than 90% of all pilots are male (Schaffernak et al., 2022). Leuenberger and Lutte (2022, p. 238) consider gender equality (SDG 5) to have "(..) powerful connections to and impacts (..)" on aviation. For decades, female aviators have needed to resist social prejudices despite having achieved remarkable accomplishments of skill and endurance (Vermeulen, 2009). While Vermeulen (2009) found that CFIs have relatively positive perceptions of female pilots, Germain et al. (2012) argue that lacking acceptance, self-efficacy, social support from organizations, flight instructors and family, as well as stereotyping are commonly encountered by women during their flight training, which often causes them to quit. Furthermore,

Schaffernak et al. (2022, p. 3) found that “learning needs and preferences of male pilots tend to be generalized to both genders”.

Mobility Injustice and Negative Environmental Image

The phrase "flying is a privilege, not a right" is commonly used in the American aviation community. This refers to the state allowing pilots to exercise their right to fly, which can be revoked if laws and regulations are broken. Reigel (2013) argues that pilots should not take this privilege for granted and must comply with regulations. However, privilege also includes strict medical requirements and financial means, which excludes certain groups from flying. For example, Swiss GA pilots are mostly male, have tertiary education, and are high-income earners (Stiebe, 2022). In the US, white pilots make up 81.7% of private pilots, with small increases in shares of Asian, Hispanic/Latino, and Black/African American private pilots over the past decade (see *Figure 12*) (ZIPPIA, 2022).

Private aviation is commonly associated with luxury and economic privilege, which reflects extensively on social media, e.g. Instagram (Cohen et al., 2022). Within the discourses on climate change and mobility justice, both commercial and general aviation are attracting increasing attention. Most GA pilots (68%) in Switzerland think GA has a negative environmental image (Stiebe, 2022). There is notable interest in the GA community to facilitate a transformation to not only improve its image and environmental impact but also to become as a leading actor in sustainable innovation (Stiebe, 2022).



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Other/Unknown	2.46%	2.13%	1.95%	2.59%	2.29%	2.46%	3.15%	2.10%	2.99%	2.70%	4.48%	5.80%
Hispanic or Latino	6.16%	5.64%	5.50%	6.03%	5.76%	6.35%	6.73%	5.83%	7.37%	6.98%	7.34%	7.04%
Asian	1.40%	1.03%	1.56%	1.81%	1.59%	1.75%	1.66%	1.89%	1.98%	2.20%	2.79%	2.76%
Black or African American	2.26%	2.20%	2.79%	2.23%	2.42%	2.10%	1.84%	2.93%	2.12%	1.65%	2.50%	2.69%
White	87.72%	89.00%	88.20%	87.34%	87.94%	87.34%	86.62%	87.25%	85.54%	86.47%	82.89%	81.71%

Figure 12: Ethnicities of Private Pilots in the United States from 2010 to 2021, based on Data from ZIPPIA (2022)

Demographic Change

Since the onset of the 21st century, GA has seen some drastic demographic changes. The main market, the United States has experienced a significant drop in the number of private pilots and number of general aviation hours flown while the average age of private pilots has increased by several years (Meyer, 2021). According to Meyer (2021), there is an indication that small aircraft (especially hobby flying) aviation activities in GA are currently in decline. Luebbers (2019) argues that aging pilots and airplanes are a current problem. This trend is also visible in the Swiss context, where GA has also seen a drastic decline in private pilots and registered aircraft (Schlittler, 2018) (see section 2.2.1.1). The average age of private pilots in Switzerland is now also above 50 years (Stiebe, 2022).

2.2.2.1.2. Sustainability Potentials in GA and PPL(A) Training

This section focuses on five pertinent areas, namely 1) noise abatement, 2) the AVGAS 100LL phaseout, 3) electric propulsion technology, 4) virtual reality and flight simulators, and 5) personal sustainability measures taken by private pilots.

Noise Abatement

Technological solutions such as propeller and muffler modifications/retrofits, electric aircraft, and Continuous Descent Approach (CDA) can reduce noise and fuel consumption (Berton & Nark, 2019; Hjelmco Oil AB, 2022; Jin et al., 2013; Scheelhaase et al., 2015). Noise-based landing charges can encourage aircraft owners to invest in noise-reducing technologies (FOCA, 2022a). Private pilots are trained to reduce noise, avoid noise-sensitive areas, and run the engine at low rpm. Computer-based training and landing fee discounts are available for pilots interested in noise abatement techniques. In Switzerland, airfields often require pilots to fly complex circuit patterns to avoid noise-sensitive areas. Noise abatement measures include adjustments to circuit geometry, altitudes, departure/arrival sectors and routes, prohibited flight times, and flight type/movement restrictions.

Noticeably, flight training is usually subject to the strictest restrictions. While 77% of the Swiss GA community believe that people are overly sensitive to GA noise emissions, 63% see a major problem in GA noise emissions (Stiebe, 2022).

AVGAS 100LL Phaseout

The AVGAS 100LL dilemma is still "one of the most pressing problems in aviation" (Cloche, 2010, p. 65). In 2022, about two-thirds of the Swiss private pilot community stated to consider the continued use of AVGAS 100LL problematic (Stiebe, 2022). Although numerous research and development attempts have been made worldwide to produce safe alternatives to AVGAS 100LL (FAA, 2014, 2019; FOCA, 2007) none have been found to be a drop-in replacement (Kumar et al., 2020). However, the FAA and EPA have established the EAGLE partnership (**E**liminate **A**viation **G**asoline **L**ead **E**missions) to transition to a lead-free GA by 2030 (FAA, 2022). While some GA aircraft can use MOGAS, concerns have been raised regarding its compatibility with fuel systems and other risks (Kumar, 2019). Retrofitting GA aircraft with *Continental* Diesel engines is also a possibility (Continental Aerospace Technologies, 2022). Several locally available lead-free fuel alternatives to AVGAS 100LL exist, including 82 UL, 91/96 UL, 94 UL, G100 UL, and UL 102 (Cloche, 2010). Pioneering work has already been done using 100% synthetic fuel (Zero Petroleum, 2021). Most Swiss GA pilots see high sustainable development potential in the future use of synfuels (55.9%) and biofuels (50.1%) (Stiebe, 2022).

Electric Propulsion Technology

FAA (2021) sees minor impact on GHG emissions but significant air quality benefits from GA electrification, while Riboldi et al. (2020) consider noise reduction as a significant improvement. The *Pipistrel Velis Electro* has gained popularity in military and private pilot training since its EASA-Type Certification in 2020. However, its limited MTOW, long charging times, high battery wear costs, sparse charger network, and short endurance currently restrict its use to basic training in PPL(A) (see *Figure 13*), complemented by fossil-fuel powered planes. Nonetheless, shorter charging times, increased endurance, and economic advantages are expected. According to Stiebe (2022), 12% of Swiss GA pilots and 18% of student pilots have flown electric aircraft, with 56% of the Swiss GA community assigning high potential to them for sustainable PPL(A) training. While responsible authorities are considering amendments to the Swiss PPL(A) syllabus, only 30% of the Swiss GA community sees high potential in syllabus adjustments to increase sustainability. The substitution of flights shorter than 40-50 minutes with electric planes can already save 41% to 45% CO_2 emissions over the PPL(A) training period.

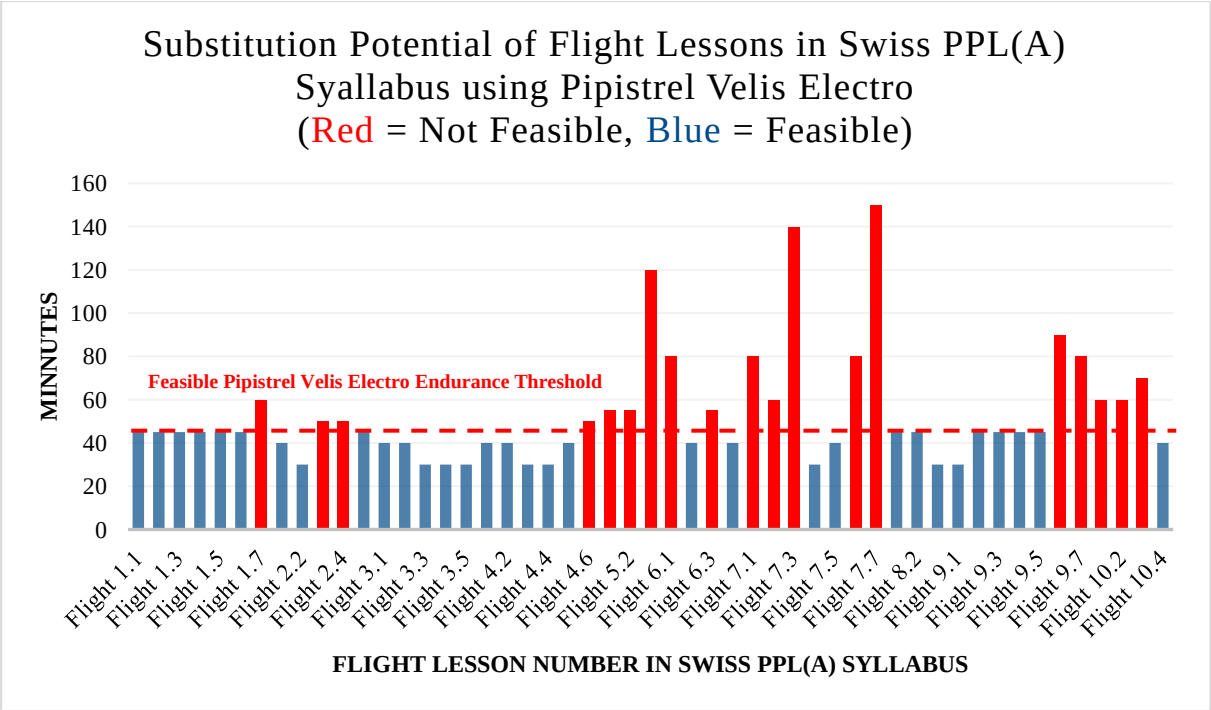


Figure 13: Substitution Potential of Pipistrel Velis Electro regarding Flights in PPL(A) Syllabus, based on Stiebe (2022)

Virtual Reality and Flight Simulators

Simulator training is common for commercial and airline pilots, but uncommon in PPL(A) training despite potential safety and sustainability benefits. Recurrent simulator-based training is required for airline pilots every six months(Taylor et al., 2014), but simulator use in PPL(A) training is limited. The use of simulators could increase safety, reduce fuel consumption, and emissions from circuit training, contributing to environmental and economic sustainability (Schaffernak et al., 2022). However, pilots and student pilots are often not allowed to log simulator flight hours, reducing the overall attractiveness of this training (Taylor et al., 2014). Only 34% of the Swiss GA community sees high potential in the use of virtual reality and flight simulations in PPL(A) training to increase sustainability (Stiebe, 2022).

Pilots' Personal Sustainability Measures

Stiebe (2022) explored personal sustainability measures taken by private pilots in Switzerland. The study showed that only a small number, i.e., 9.7%, of private pilots do not take any measures for sustainability related to their flying activities. The most common sustainability measures showed to be the use of noise reduction flight tactics (50.8%), unleaded fuels (19.8%), other measures 11.9% (e.g., no kids, flying less etc.), CO_2 compensation (4.4%), and the use of electric planes (3.5%).

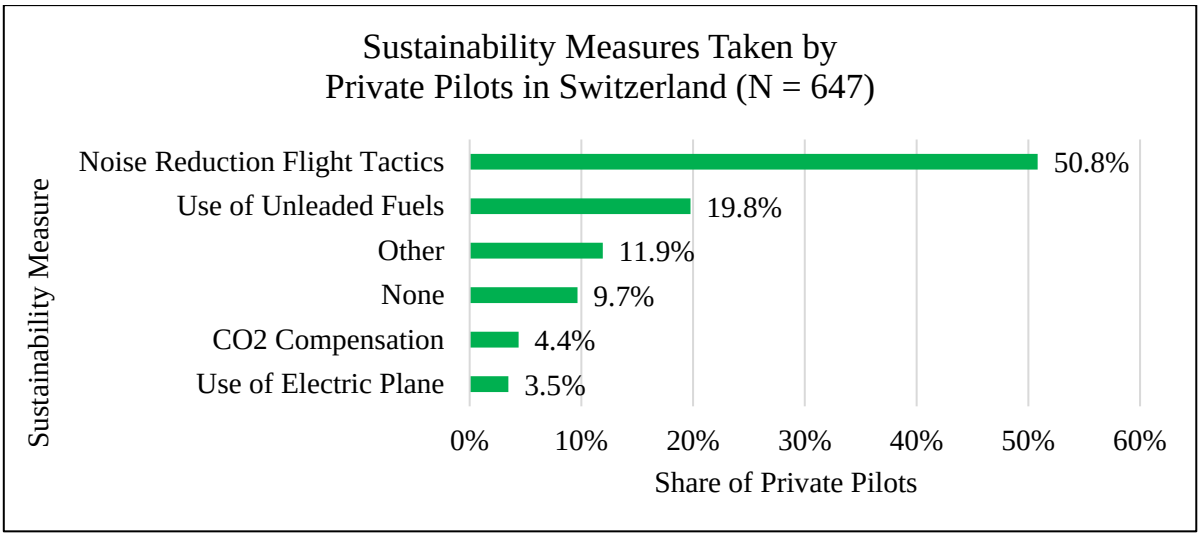


Figure 14: Personal Sustainability Measures Taken by Private Pilots in Switzerland, based on data from Stiebe (2022)

3. Literature Overview

This chapter shall summarize the status quo of academic research pertaining to sustainability and sustainability education related to PPL(A) training. Thus far, PPL(A) training has neither been a common research focus in the fields of educational science nor ESD, which highlights the research gap.

First, it is crucial to discuss where PPL(A) training is to be allocated on the spectrum of education. There are three commonly recognized types of education, namely 1) Formal Education, 2) Non-Formal Education, and 3) Informal Education (Dib, 1988). According to Manolescu et al. (2018), this standard typology which was developed in the mid-1970s "(..) relies on the variety of learning situations, its intention, purpose and the way of manifestation in time" (p. 8). Based on the criteria defined in forecited publications, PPL(A) training is primarily allocatable to the formal spectrum of education (Alluisi, 1997) as it corresponds to a systematic, organized education model, structured and administered according to a given set of laws and norms, presenting a rather rigid curriculum while basing on the triad: teacher – student – institution (Dib, 1988). In the case of the research focus, PPL(A) training, there are institutions (e.g., "flight schools", "flying schools", "flight academies", "pilot academies", etc.) students (student pilots), teachers (certificated flight instructors), laws (e.g., EASA, FOCA, FAA, ICAO regulation) and a given organized education model with a PPL(A) syllabus/curriculum[4] (with rigid requirements). Nevertheless, pilot training does also involve non-formal education aspects such as distance learning, learning outside the classroom, et cetera. Such hybrid forms and overlaps are a common phenomenon in education (Manolescu et al., 2018).

It is important to highlight that motor pilot training involves mostly[5] adult student pilots. This ESD research is therefore expected to also contribute to a segment of education that, according to Orlović Lovren and Popović (2018), has often been left behind in the overall sustainability education perspective, namely adult education. To summarize, PPL(A) training falls under the category of formal education and could due to its demographic makeup be considered a form of formal adult education.

[5] Global statistics are sparse, but in the U.S., the average age of private pilot student pilots is currently 33, see e.g., https://www.planeandpilotmag.com/article/empty-nester-private-pilot

3.1. Sustainability in PPL(A) Training

Whereas some papers have already addressed sustainability aspects in private pilot training, none of the academic publications has addressed ESD or sustainability education in this field.

The literature review involved searching different online tools and databases for relevant literature on sustainability and SD in PPL(A) training, including Google Scholar, Scopus, Web of Science, and JSTOR. No publication time limit was set, and quotations were excluded. The process had four phases, including defining search queries and databases, filtering results based on specific criteria, and manually reviewing and integrating relevant literature. For a detailed overview of the process and its results, please see Appendix 2.

3.1.1. Perceptions of Sustainability Challenges and Opportunities

The perceptions, concerns and visions of key stakeholders in PPL(A) training regarding sustainability challenges and opportunities are important to understand the sustainability transition in this field.

Hitherto, only one academic study has investigated the perceptions of sustainability issues in PPL(A) training. Stiebe (2022) conducted a mixed-methods study, i.e., "Come Fly with Me (Sustainably): Pathways to Sustainable General Aviation and Private Pilot Training", with a focus on the Swiss GA community combining a quantitative survey (N = 427) with student pilots, flight instructors, private pilots, and eight expert interviews with Swiss and international GA stakeholders. In this study, the quantitative survey showed that the majority (79%) of pilots, student pilots and flight instructors are concerned about sustainability in private pilot training. While only 30% of the respondents expressed that environment and sustainability are insufficiently addressed in practical PPL(A) training, more than 41% of respondents thought that these topics are insufficiently addressed in theoretical PPL(A) training (compared to 23% thinking they are sufficiently addressed). Furthermore, the survey results clearly showed that while greenhouse gas emissions are not a major concern, the community is concerned with the negative image of GA, both a perceived oversensitivity to noise emissions of inhabitants as well as GA's noise emissions themselves, and the continued use of leaded aviation gasoline in GA (see also Figure 15). The study identified that the four largest perceived obstacles to sustainable development in GA and PPL(A) training are 1) bureaucracy, overregulation and politics, 2) high costs, 3) low environmental consciousness/attitudes, and 4) fear of new ideas, innovation, and risk averseness. In terms of visions and solutions for a more sustainable PPL(A) training, the survey results revealed that the GA community sees the largest potentials for increased sustainability in the use of electric airplanes,

synthetic fuels and biofuels, and increasingly addressing environmental and sustainability topics more in-depth in theoretical PPL(A) lessons (see *Figure 16*).

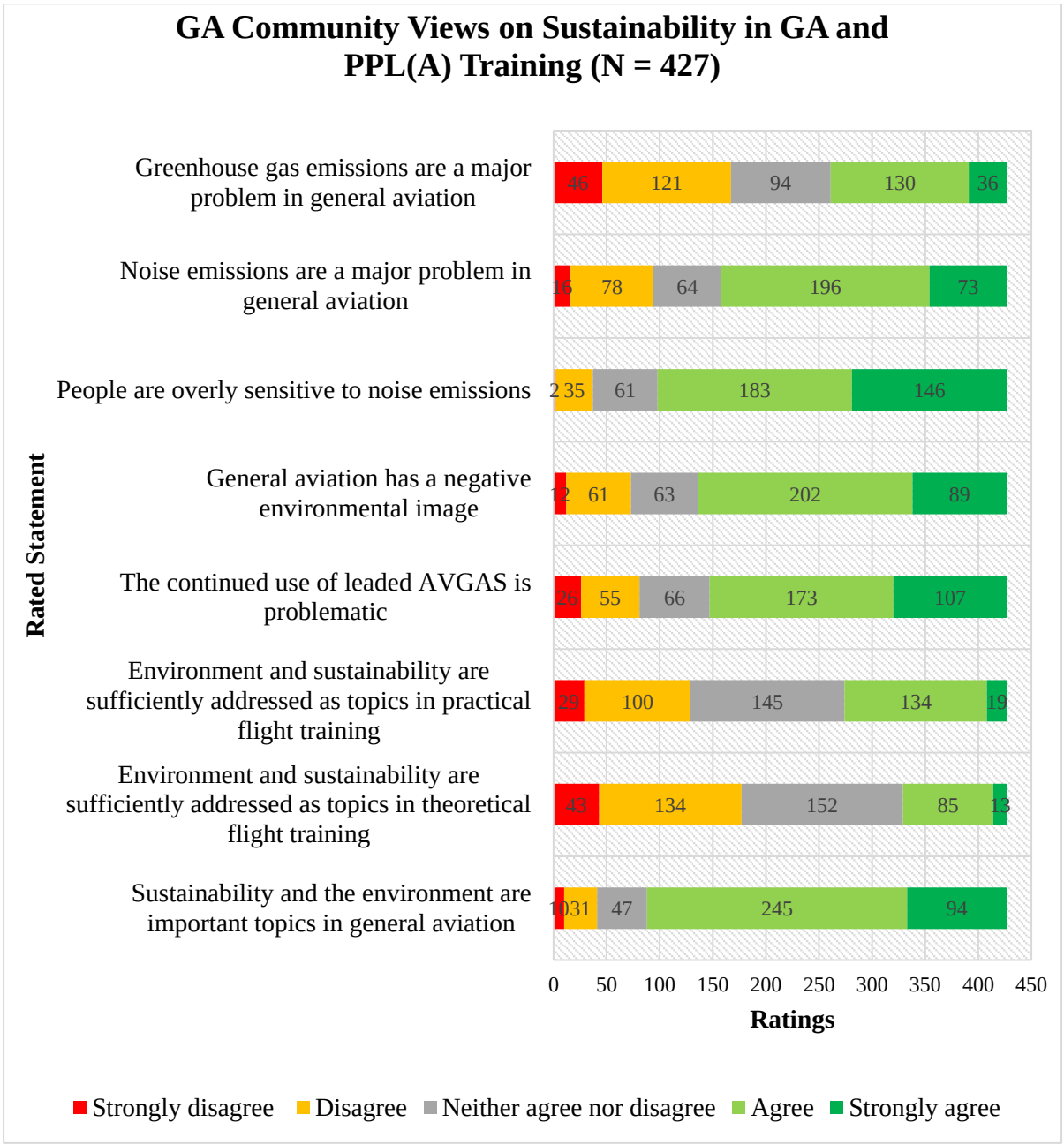


Figure 15: Swiss GA Community Views on Sustainability Issues in GA and PPL(A) Training, from Stiebe (2022, p. 30)

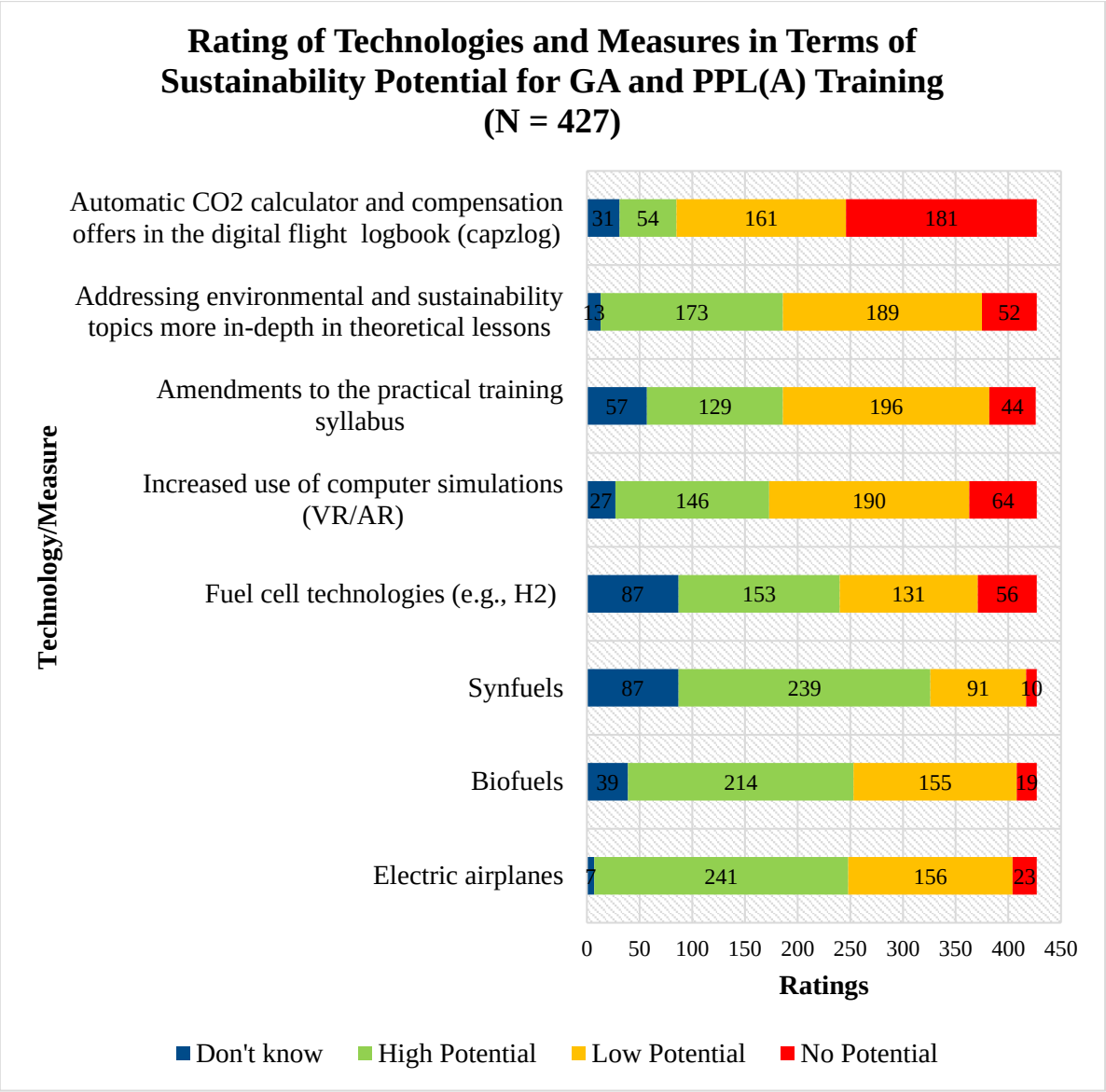


Figure 16: Rating of Sustainability Potential of Technologies/Measures for GA/PPL(A) Training, from Stiebe (2022, p. 38)

3.1.2. Electric Aviation

In his master's thesis titled "eVTOLs and Pilot Training - The Impact of Electric Vertical Takeoff and Landing Aircrafts to Pilot Training", Voipio (2022) aims at depicting how eVTOLs could impact pilot training. The study drew on a multi-method approach combining an extensive literature review and seven qualitative interviews with industry experts. Since eVTOLs are not yet established in the market, the study has major constraints and should be rather regarded as a trendspotting or scoping study. Voipio (2022) makes no clear statement about how eVTOLs will impact flight training. He considers the

probability of eVTOLs impacting GA or private aviation quickly as relatively low yet speculates that there will be a private eVTOL segment in GA which will mean "[p]eople will have the chance to travel between destinations in their own personal eVTOL. Once this is possible, private VPLs[6] will be provided by smaller modern driving school type flight schools" (Voipio, 2022, p. 61).

In their conference paper "The E-Fan all electrical aircraft demonstrator and its industrialization", Joubert et al. (2016) present an all-electric aircraft concept, which would bring flight emissions down to zero, and discuss its potential sustainability implications as well as potential impact on flight training. The paper is an engineering-themed conceptual paper presenting technological development progress. The authors conclude that the all-electrical aircraft, E-Fan 2.0, will be ideal for the initial training of private pilots, and even thereafter "(..) introduce an essential number of electrical aircraft into real day to day flight application thus paving the way for electrical-/hybrid propulsion step by step to larger aircraft" (Joubert et al., 2016, p. 6).

Edwards and Parker (2022) published a scientific paper titled "Flight School Perceptions of Electric Planes for Training" which reports the findings of a survey-based study that investigated flight school community perceptions of e-planes for flight training with regard to perceptions on the safety of the technology, trust in the technology, their perceptions on cost differences between training on conventional or electric planes, and what reasons would be important for them to want to fly e-planes. The sample consisted of 186 people, 117 student pilots, 35 CFIs, 15 flight school managers/owners, and 19 "others". The main geographic focus was mainly on Canadian (85%) and Indian (13%) flight training stakeholders. The survey results indicated that the flight school community, including student pilots, flight instructors, managers/owners, and others, have a positive view of e-planes for flight training, but some concerns remain about battery endurance, charging time, and winter operations. Educating stakeholders on the benefits and limitations of electric aircraft is crucial to promote wider adoption. The high demand for e-planes in flight training suggests that investing in the technology and testing it under local conditions is a necessary next step. Edwards and Parker (2022) concluded that electrification of flight training has the potential to lead to significant emissions reductions in Canada and globally. A key constraint of the abovementioned study is that the flight schools investigated in the study were neither in the possession of nor had access to electric planes at that time of the research.

Thus far, the only empirical academic study addressing, among other sustainability subjects, perceptions on electric planes in pilot training in a context where survey respondents had access to and already used electric airplanes, is the master's thesis study "Come Fly with Me (Sustainably): Pathways to

[6] VPL = VTOL Pilot License

Sustainable General Aviation and Private Pilot Training" by Stiebe (2022). In his mixed-methods study with a focus on Switzerland's GA community, the author investigated experiences and perceptions regarding electric airplanes in GA and PPL(A) training. The survey results (N = 427), indicated that, at the time of the survey in Stiebe (2022), i.e. May 2022, 12% of Swiss GA pilots and 18% of student pilots had already flown an electric aircraft, foremost the Pipistrel Velis Electro. It showed, that the majority (56%) of the Swiss GA pilot community assigns high potential to electric airplanes for more sustainable PPL(A) training (Stiebe, 2022). However, it should be noted that, in the community, 37% and 5% only saw low or no potential, respectively. For those respondents who had already flown electric, the main reasons for flying electric planes were trial flights/testing the technology and its potential (51%), learning flying (24%), and teaching flying (11%). Furthermore, the study depicted that the use of Pipistrel Velis Electro is still rather limited in use for PPL(A) training due to its low MTOW, long charging times, high battery wear costs, sparse charger network, and short endurance (Stiebe, 2022). Thus, currently only short flight sessions and basic training in the PPL(A) are and can be substituted by this type of plane, usually complemented by the use of fossil-fuel engine-powered planes (Stiebe, 2022). Nevertheless, the study showed that over the course of a standard PPL(A) training, this can already save up to 41-45% CO_2 emissions.

3.1.3. Gender-Related Aspects

In their non-empirical paper "Sustainability, Gender Equity, and Air Transport: Planning a Stronger Future" which drew exclusively on review of U.S. statistics and secondary data, Leuenberger and Lutte (2022) have a slight focus on private pilot training in relation to gender equality. Leuenberger and Lutte (2022) suggest that gender equality (SDG 5) has powerful connections to and impacts on aviation. They analyzed FAA statistics and point out that, over the past 15 years, the category of private pilots has experienced less than a 0.3% increase in women, currently being at a total share of 6.6%. Their reasoning to label this as "particularly concerning" is based on the fact that PPL training "represents the first step in the pipeline to becoming a professional pilot" (Leuenberger & Lutte, 2022, p. 241).They concluded that the inclusion of women in aviation has important implications for a sustainable and just future and identified eight major opportunities for aviation that can lead to a better future. These can be summarized as follows:

1. Increase women in aviation leadership, management, and pilot roles, with focus on regulatory agencies and airports. Public institutions (e.g., FAA) can help by creating diversity programs.

2. Address workplace barriers to retain women in aviation, including gender bias, discrimination, and family supportive policies. Public policy change should involve industry input.
3. Recognize and value the work of women in areas such as flight attendants.
4. Evaluate women's impact on sustainable action, including their willingness to pay for carbon offsets. Funding sustainable initiatives may expand user fees and benefit public infrastructure.
5. Increase women's involvement in decision-making for aviation infrastructure.
6. Provide intersectional education about bias and inequality in the aviation industry and supporting government agencies.
7. Incorporate impacts on women in decision-making for social, environmental, economic, and sustainability goals.
8. Focus on climate change and fuel consumption, building on COVID-19's environmental gains due to lower consumption during that time.

(Leuenberger & Lutte, 2022)

3.1.4. Safety-Related Aspects

Safety is still the largest concern in aviation. In terms of sustainable development, safety in aviation can be directly related to SDG 3 – Good Health and Wellbeing. Bird strikes are one of the most severe risks pilots are exposed to while flying. Not only do bird strikes mean harm to wildlife and often human lives, even deaths in the worst cases, but also major economic damage.

In their paper “Enhancing the Aeronautical Decision-Making Knowledge and Skills of General Aviation Pilots to Mitigate the Risk of Bird Strikes: A Quasi-Experimental Study”, Mendonca and Keller (2022) aimed to assess whether a workshop on aeronautical decision-making (ADM) could enhance collegiate aviation pilots' skills and knowledge in preventing bird strike-related accidents. They report the findings from a quasi-experimental study involving a sample of 107 pilots, CFIs and student pilots, who all were students enrolled in the course “safety management of wildlife hazards by pilots”. The study found a statistically significant improvement in the post-test scores which indicates that such preventive safety courses for pilots can improve their ADM skills and lead to lower bird strike risks, which is why the authors recommend that such measures may contribute to sustainability and sustainable growth in aviation. They identify five main benefits of such training courses:

1. Reducing the direct and other monetary losses resulting from bird strikes.

2. Reducing the number of human injuries and fatalities resulting from bird strikes.
3. Increasing the quantity and improving the quality of wildlife strike reports by pilots.
4. Supporting the sustainable growth of the U.S. aviation industry.
5. Providing pilots with unique opportunities to develop or enhance competencies (e.g., risk management) that are valued by the aviation industry.

3.1.5. Summary

While neither sustainability nor sustainable development have been addressed to any major extent in academic studies concerning GA, PPL(A) training has received even less scholarly attention in this regard. The few published papers that exist to date have not taken into account perspectives of educational science or even ESD. Most papers published research related to sustainability in GA or PPL(A) training are concerned with engineering, environmental, or safety perspectives.

Some exceptions included the studies by Edwards and Parker (2022); Stiebe (2022) who incorporated GA and PPL(A) stakeholder perceptions on sustainability, or Leuenberger and Lutte (2022) who inquired gender-related issues in PPL(A) training. The literature overview has underlined the fact that the research topic of this thesis has, thus far, nearly flown under the radar, which highlights the research gap and emphasizes the importance of this research.

4. Theory

This chapter summarizes and elaborates on theoretical frameworks and constructs that this research draws on to answer the stated research questions. As a whole, this research is framed within the field of Education for Sustainable Development (ESD) and approaches the research subject on the secondary level using Jack Mezirow's Transformative Learning Theory which has become an essential component in ESD.

4.1. Education for Sustainable Development ESD

The historical roots of Education for Sustainable Development (ESD) date back to the United Nations Conference on Environment and Development (UNCED) in 1992 (Buckler & Creech, 2014). At the UNCED, 178 member states decided on a framework for action in Agenda 21 in which Chapter 36, recognizes education, training and public awareness as critical tools for the transition to sustainability by advocating for a reorientation of education towards sustainable development (Buckler & Creech, 2014). In this reorientation process of education described in Chapter 36, the United Nations Educational, Scientific and Cultural Organization (UNESCO) was assigned a critical role (Buckler & Creech, 2014). The principles and underlying frameworks of Agenda 21 guide both planning and conceptual thinking for ESD on global and local levels (Buckler & Creech, 2014).

According to Boeve-de Pauw et al. (2015, pp. 15695-15696), UNESCO defines ESD as follows:

> "Education for Sustainable Development means including key sustainable development issues into teaching and learning; for example, climate change, disaster risk reduction, biodiversity, poverty reduction, and sustainable consumption. It also requires participatory teaching and learning methods that motivate and empower learners to change their behavior and take action for sustainable development. Education for Sustainable Development consequently promotes competencies like critical thinking, imagining future scenarios and making decisions in a collaborative way."

According to Kopnina (2014, p. 189), the World Conference on Education for Sustainable Development (2009) defined ESD as "(..) an approach to teaching and learning based on the ideals and principles that underlie sustainability".

Frequently, sustainability and SD are wrongly reduced to dealing exclusively with environmental and, more recently, climate change issues. This has also affected ESD as it is often confused with or seen as a variant of Environmental Education (EE). EE and ESD must not be confused. These concepts relate to each other in such a way that EE could be considered to be a vital component of ESD (Wals & Kieft, 2010).

ESD uses a holistic approach that draws on key principles focusing among others on critical thinking and capacity building, and sustainability-centered curricula (Pandey & Vedak, 2010). In the view of Hopkins and McKeown (2002), ESD must focus on knowledge and skills to provide practical capabilities that will enable people to learn beyond graduation (life-long learning), secure sustainable livelihoods, and live sustainable lives. It must be noted that the necessary skills will differ with community conditions (Hopkins & McKeown, 2002). There are currently four major thrusts of and seven strategies for ESD which are summarized below in *Table 1*.

Table 1: Four major thrusts of ESD and seven strategies for ESD, based on Buckler and Creech (2014, p. 17)

Four Major Thrusts of ESD		**Seven Strategies for ESD**	
I.	**Improving access and retention in quality basic education**	I.	Vision-building and advocacy
II.	**Reorienting existing educational programs to address sustainability**	II.	Consultation and ownership
III.	**Increasing public understanding and awareness of sustainability**	III.	Partnership and networks
IV.	**Providing training to advance sustainability across all sectors**	IV.	Capacity-building and training
		V.	Research and innovation
		VI.	Use of Information and Communication Technology (ICT)
		VII.	Monitoring and evaluation

The debate around the still evolving field of ESD is lively and critical. For instance, Kopnina (2012) argues that ESD may undermine everything socially critical EE stands for as well as EE's efforts of educating people in the importance of appreciating and protecting the environment. Further critique includes the thoughts of Ideland and Malmberg (2015) who argue that ESD may aim at producing "eco-certified children" that are the opposite of the "dangerous children" applying a responsibilization perspective to students in saying: "You are the problem for our common future" (Ideland & Malmberg, 2015, p. 181). In addition, ESD is often critiqued of being subject to substantial anthropocentric bias

placing humanity in the center of the sustainability and SD debate (Bylund et al., 2022; Kopnina, 2012, 2014). Lastly, pluralistic interpretations of ESD are said to increase the risk of inducing confusion in both educators and students concerning the inherent problems and contradictions of SD (Kopnina, 2012).

4.2. Transformative Learning Theory

Transformative learning theory is a theory of adult education and development, developed by Jack Mezirow in the late 1970s, suggesting that learning can fundamentally alter understanding of the self and the world (Glavič, 2020; Kitchenham, 2012; Simsek, 2012). The theory is strongly influenced by the works of Paulo Freire (particularly emancipatory education) and Jürgen Habermas (Mezirow, 2008). According to Kitchenham (2012, p. 1659) , the central element of the theory "(..) is the argument that adults experience a catalyst that causes them to question their worldview, the disorienting dilemma, which leads to a fundamental change in the way that they view the world". Throughout the 30 years after its initial foundations were laid, the theory has been further developed and refined by Mezirow and other scholars since then (Kitchenham, 2008, 2012). In his original theory, Mezirow described ten phases of transformative learning which are listed in *Table 2*.

Table 2: Ten Phases of Mezirow's Transformative Learning, based on Kitchenham (2012)

PHASE	PHASE DESCRIPTION
1	A disorienting dilemma
2	A self-examination with feelings of guilt or shame
3	A critical assessment of epistemic, sociocultural, or psychic assumptions
4	Recognition that one's discontent and the process of transformation are shared and that others have negotiated a similar change
5	Exploration of options for new roles, relationships, and actions
6	Planning of a course of action
7	Acquisition of knowledge and skills for implementing one's plans
8	Provisional trying of new roles
9	Building of competence and self-confidence in new roles and relationships
10	A reintegration into one's life on the basis of conditions dictated by one's perspective

Transformative learning has gained increasing impetus as well as recognition, and is considered vital to enhancing and catalyzing sustainability transformations (Boström et al., 2018; Rodríguez Aboytes & Barth, 2020). According to Glavič (2020), transformative teaching, learning, and training have become a key issue in ESD aiming at producing agents of change. Rodríguez Aboytes and Barth (2020) argue that ESD has embraced transformative learning to overcome its conventional approach and to support an education which will lead "(..) to the transformation of unsustainable mindsets and the adoption of a paradigm towards sustainability" (p. 994).

In transformative learning, students embark on a journey of critical thinking and discovery. In this process, Mezirow (1997) describes the educator as a *facilitator* and *provocateur* rather than as an authority on subject matter.

As has been reasoned in Chapter 3, PPL(A) training is to be allocated on the spectrum of formal adult education. Aiming at finding ways to catalyze the sustainability transition in this field, transformative learning theory appears to be an ideal theoretical lens through which the research problem can be investigated. This underpinned by Mezirow's (1997, p. 11) conclusion that "transformative learning is not an add-on. It is the essence of adult education".

5. Method

The chapter outlines the research strategy, data collection, processing, and analysis. It ends with a critical reflection on the methodology's reliability and limitations, and ethical considerations.

5.1. Research Strategy

This section elaborates on the research paradigm, theoretical perspective, and research methodology.

5.1.1. Research Paradigm and Theoretical Perspective

This research is embedded in the research paradigm of pragmatism. It originated in the late 19th and early 20th centuries in the United States, and is associated with philosophers and thinkers such as Charles Peirce, William James, and John Dewey (Ormerod, 2006). Pragmatism emphasizes practical consequences and empirical observation in guiding inquiry. It rejects the notion of a fixed or absolute reality, and emphasizes the importance of personal experiences in constructing knowledge. Pragmatists are interested in studying how people make meaning of their experiences and how different perspectives shape understanding. They emphasize the use of a variety of research methods and close ties to practice. Pragmatism is associated with mixed-methods and multi-method research, and emphasizes problem-solving (Kaushik & Walsh, 2019; Maxcy, 2003; Parvaiz et al., 2016)

5.1.2. Methodological Choice and Research Design

This multi-method research draws on multiple methods, namely a thematic document analysis of exemplary PPL(A) learning material, and qualitative semi-structured interviews with student pilots/recently certificated private pilots and CFIs to answer the research questions. The first research question was based on propositions generated from the author's preceding research project which explored sustainability issues and pathways in GA and PPL(A) training from a broader perspective (Stiebe, 2022). In said study, the quantitative survey results revealed that about one-third of the GA community thinks that environment and sustainability are insufficiently addressed in practical PPL(A) training, and more than 41% think that these topics are insufficiently addressed in theoretical PPL(A) training. Further findings from that study were used to generate *a priori* codes, which were later used in the document and interview analyses described in section 0.

5.2. Data Collection

This section outlines the data collection processes used in this research.

5.2.1. Secondary Data Collection

The secondary data collection process involved two steps: gathering relevant academic and grey literature to review the current state of research and technological advancements, and obtaining and digitizing Swiss PPL(A) theory learning material for document analysis.

For the thematic document analysis, a selection of pertinent PPL(A) learning materials was acquired. From his 2020-2022 PPL(A) training, the author was in the possession of some of the most commonly used official Swiss training materials (see *Table 3*)

Table 3: Overview of PPL(A) Learning Material for Document Analysis

DOCUMENT TYPE	DOCUMENT TITLE	PUBLISHER/ AUTHOR	YEAR	NO. OF PAGES	ANALYZED CONTENT
SWISS PPL(A) FLIGHT INSTRUCTION SYLLABUS-ADJUSTED PRACTICAL TRAINING MATERIAL	*ÜBERSICHT ÜBER DIE GRUNDLAGEN UND VERFAHREN FÜR DIE FLIEGERISCHE BASISAUSBILDUNG (GuV)*[7]	SPHAIR, SWISS FEDERATION/ SWISS AIR FORCE	2023	528	SUSTAINABILITY AND ENVIRONMENTAL TOPICS IN PRACTICAL PPL(A) TRAINING
TEXTBOOK FOR NINE MANDATORY PPL(A) THEORY SUBJECTS	*BASIC AVIATION KNOWLEDGE (BAK)* (*ISBN 978-3-905036-48-0*)	BAK-LEHRMITTEL-VERLAG	2020	1,500	SUSTAINABILITY AND ENVIRONMENTAL TOPICS IN THEORETICAL PPL(A) TRAINING

[7] Obtained from https://www.sphair.ch/sphair/documents/10804/1485594/2023_GUV_d.pdf/, March 1, 2023

5.2.2. Semi-Structured Qualitative Interviews

This study entailed six qualitative semi-structured interviews, three with CFIs and three with student pilots/recently certificated private pilots. Both groups were included to provide comprehensive answers to the research questions and ensure a balanced discussion.

5.2.2.1. Sampling Process and Sample Description

The quantitative dimension of interviewee sampling in qualitative research and the related question "How many interviews are enough?" are frequently discussed issues in academia as for instance reflected in Francis et al. (2010); Guest et al. (2006); Rowlands et al. (2016). Generally, the goal in qualitative research is to reach the point of *Theoretical Saturation*, a concept that originally stems from Glaser and Strauss' methodology of *Grounded Theory* whose foundations were laid in 1967 (Rowlands et al., 2016; Saunders et al., 2018). The number of interviews a researcher is able to conduct in a study is subject to certain limitations such as available time, skill, experience, research funding, among others.

The author consulted the methodology portal (German: "Methodenportal") of Leipzig University that. recommends a number of six to seven interviews for master's thesis research projects conducted within one semester's or six months' worth of time(Leipzig University, n.d.).

Besides being able to speak German or English and being based in Switzerland, CFIs had to be active (i.e., not retired) practical, or active and theoretical, flight instructors for PPL(A), and student pilots/recently certificated private pilots: had to be at least on training stage 8 (out of maximum 10 stages in syllabus) OR recently certificated private pilots (PPL(A)) (practical skill test within last 12 months).

The interviewees in both groups were selected using convenience and snowball sampling. The sample was limited to white men, ranging from 19 to their mid-50s, with one Spanish expat, and all but one were Swiss nationals. The interviewees came from various professions, such as a university lecturer and digital communication manager (see *Table 4*)

Table 4: Overview of Interviews

No.	Date	Mode	Lang.	Profession	Interviewee Category	Sex	Region
1	03/18/23	Video Call	EN	Commercial Pilot	CFI	M	Central CH[8]
2	03/19/23	Video Call	DE	Digital Communication Manager (Aviation Industry)	Former Student Pilot (Checkride 02/2023)	M	Central CH
3	03/19/23	Voice Call	DE	Apprentice (Aviation Industry)	Student Pilot (Exam Preparation Phase)	M	Central CH
4	03/20/23	Video Call	DE	Catering Worker / ATPL Student Pilot	Former Student Pilot (Checkride 09/2022)	M	NW CH
5	03/22/23	Face-to-Face	DE	Lecturer in Informatics	CFI	M	Central CH
6	03/24/23	Voice Call	DE	Electrical Engineer	CFI	M	Central CH

5.2.2.2. Interview Technique

Semi-structured in-depth interviews were conducted for this qualitative research project, with a set of predetermined questions or topics to explore and guide the conversation. The interviews were conducted via telephone or video calls, except for one face-to-face interview. Two interview guides were created, one for CFIs and one for student pilots/recently certificated private pilots (see Appendices 3 and 4). The interview guides comprised five phases, each with a certain number of core questions and potential follow-up questions, and were produced in German and English. The interview questions were inspired by the interview guides in Stiebe (2022) as well as based on the findings from the literature review for this thesis. The scope of the guides was designed for interviews of an approximate duration of 30 minutes. The actual average interview time was slightly more (Ø = 32.5 minutes), but within tolerance limits. Audio recordings were made using the author's smartphone and tablet computer for redundancy, and then manually transcribed (verbatim[9]) in Microsoft Word. Swiss German interview recordings were transcribed in Standard German, and the German interview transcripts were later translated into English for data analysis.

[8] NW = Northwest, CH = Switzerland

[9] Filler words like “erm”, “uh”, “uhm”, etc. were not transcribed

5.3. Data Processing and Analysis

This section describes and explains how the collected data were processed and analyzed. This includes the document analysis, interview analysis, and the triangulation and result interpretation approach.

5.3.1. Document Analysis

This research used a thematic document analysis approach with a coding scheme inspired by a prior study (Stiebe, 2022). The approach was a hybrid of deductive and inductive coding, with primary codes and subcodes used for indexing and categorizing data. Proudfoot (2022, p. 15) concludes that "inductive/deductive hybrid thematic analysis can be seen as highly facilitative of a truly integrative approach to mixed methods research". *Atlas.ti* (version 23) was used for the coding process, and the codebook is provided in *Appendix 6: Thematic Analysis Codebook*. The document analysis followed Braun and Clarke's (2006) methodology which involves six key phases being described in *Table 5*.

Table 5: The Six Phases of Thematic Document Analysis, based on Braun and Clarke (2006, p. 87)

Phase No.	Phase Name	Description of Process
1	**Familiarizing yourself with your data**	Transcribing data (if necessary), reading and re-reading the data, noting down initial ideas.
2	**Generating initial codes**	Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code.
3	**Searching for themes**	Collating codes into potential themes, gathering all data relevant to each potential theme.
4	**Reviewing themes**	Checking if the themes work in relation to the coded extracts (Level 1) and the entire data set (Level 2), generating a thematic 'map' of the analysis.
5	**Defining and naming themes**	Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme.
6	**Producing the report**	The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a scholarly report of the analysis.

5.3.1.1. Familiarization and Document Preparation

Due to his relatively recent PPL(A) flight training, the documents to be analyzed were already widely familiar to the author. However, he decided to read through both documents again in preparation for this study and to be fully familiarized with the material as suggested in Braun and Clarke's methodology.

Due to the unavailability of the "Basic Aviation Knowledge BAK" textbook in digital form, the author had to digitize all 1,500 pages using a home printer/scanner. However, the slow scanning speed and frequent paper jams made the process more time-consuming than anticipated. The scanned pages were merged chapter-wise using PDF24[10], and then underwent Optical Character Recognition (OCR) to make the text machine-readable. The accuracy of each OCR'ed chapter was manually checked. During the analysis in *Atlas.ti* version 23, each subject in BAK was treated as a separate document. The practical syllabus-oriented textbook "Grundlagen und Verfahren" (GuV) by SPHAIR is available for free online as a machine-readable PDF comprising 528 pages.

5.3.1.2. Generation of Initial Codes

As this thematic document analysis was deductively guided, initial codes were not based on the text as it would have been done in the more common inductive approach. The initial five main codes and 35 subcodes (approx. 51% of later total codes) were derived from the findings in Stiebe (2022) as well as guided by the theoretical framework and research questions of this study.

The initial codes were 1) Sustainability (23 subcodes) 2) Practical Learning (4 subcodes), 3) Practical Teaching (4 subcodes), 4) Theory Learning (2 subcodes), and 5) Theory Teaching (2 subcodes). An overview of these is provided in *Table 6* – the full codebook with the initial codes and the ones that emerged during the analysis process can be found in *Appendix 6: Thematic Analysis Codebook*.

[10] Available under: https://www.pdf24.org/en/

Table 6: Initial Codes based on Findings from Stiebe (2022), and Theoretical Thesis Framework

MAIN CODES	SUSTAINABILITY	PRACTICAL LEARNING	PRACTICAL TEACHING	THEORY LEARNING	THEORY TEACHING
SUBCODES	Climate Change	Electric Airplane	Noise Abatement	Learning Material	Noise Abatement
	CO2 Compensation	Role of Sustainability	Role of Sustainability	Role of Sustainability	Role of Sustainability
	CO2 Emissions	Simulator	Syllabus		
	Electric Airplane	Syllabus	Ways to Address Sustainability		
	Environment				
	Environmental Conscience				
	Flight Shaming				
	Flying Techniques				
	Fuel Economy				
	Health				
	Hydrogen Propulsion				
	Issues and Challenges				
	Leaded Fuel				
	Leaning and Mixing				
	Learning Material				
	Noise				
	Noise Abatement				
	Personal Measures				
	Potentials				
	Role in Personal Life				
	Sustainable Aviation				
	Technology				
	Visions				

5.3.1.3. Searching, Reviewing and Naming Themes

After the coding process was concluded, the author checked if the themes worked in relation to the coded extracts and the entire data set. In a continuous analysis process, the specifics of each theme were refined, and the overall story the analysis tells, generating clear definitions and names for each theme.

5.3.2. Interview Analysis

The analysis of the interviews followed the same methodology as described in section 5.3.1., which entailed the steps Data Familiarization, Generation of Initial Codes, Search for Themes, Review of Themes, and Definition as well as Naming of Themes.

5.3.3. Triangulation and Interpretation

The results from both the document and interview analyses were triangulated and interpreted to answer the stated research questions. In detail this meant that to answer RQ1, the results from document analysis and the interview analysis were used combinedly. RQ2 was answered by consulting the results of the interview analysis and putting these in close relation to the theoretical framework of transformative learning outlined in section 4.2.

5.4. Methodological Summary and Timeline

This section summarizes the methodology (see *Figure 17*) and timeline (see *Figure 18*) of this thesis.

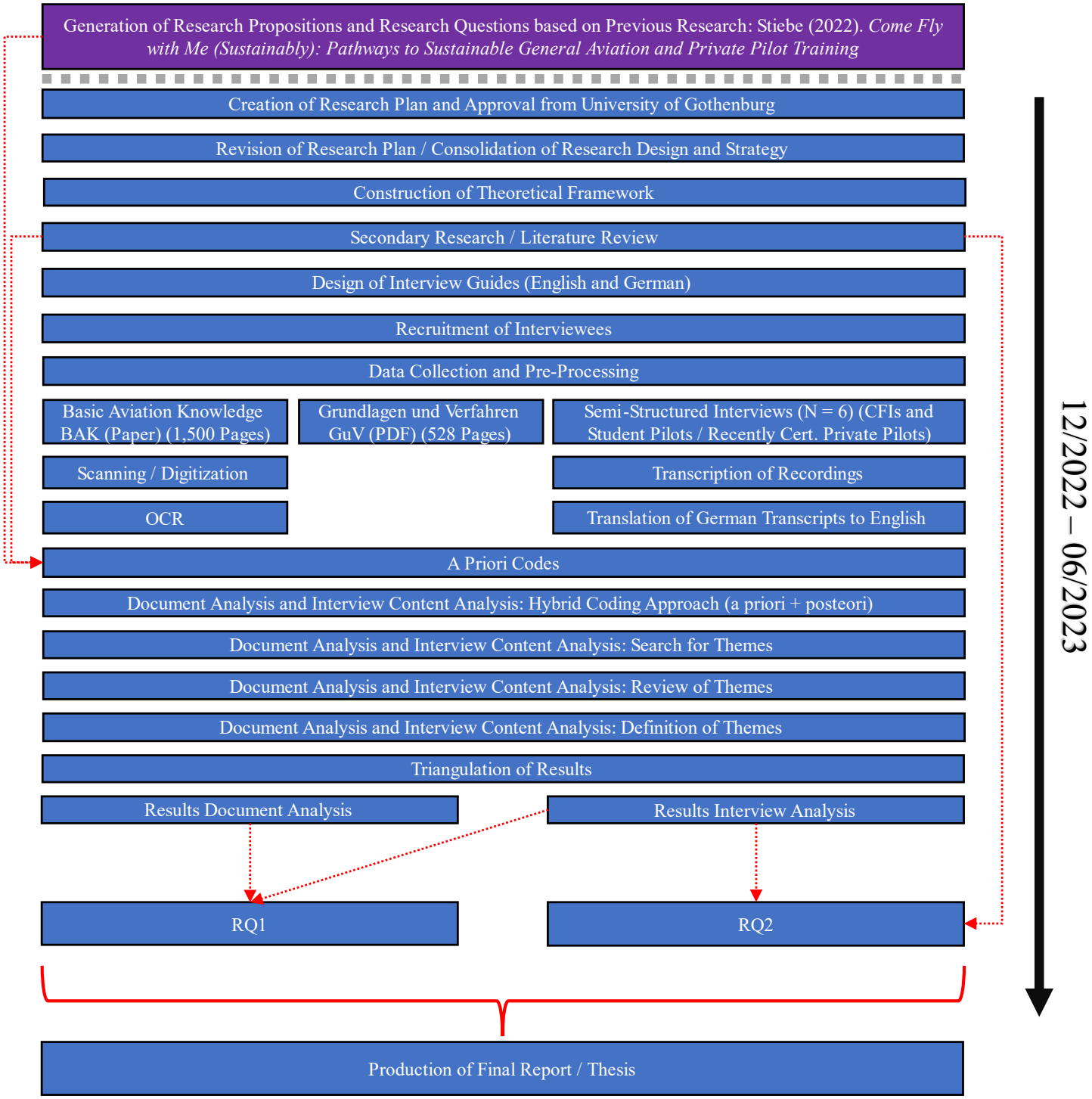


Figure 17: Overview of Thesis Methodology

RESEARCH ACTIVITY	2022				2023																					
	WEEK																									
	49	50	51	52	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Creation of Research Plan					MS1																					
Literature Review																										
Data Collection: PPL(A) Learning Material																										
Digitization of PPL(A) Learning Material															MS2											
Interviewee Recruitment																										
Semi-Structured Interviews																										
Transcription and Translation of Interviews																										
Document Analysis																						MS3				
Interview Analysis																						MS4				
Data Triangulation																										
Write-Up of Thesis																										
Submission of Thesis																										
Defense of Thesis																									MS5	
Revision and Final Submission																										MS6

MILESTONES (MS)
MS1 - Research Plan Completed
MS2 - Learning Material Collected and Digitized
MS3 - Document Analysis Completed
MS4 - Interview Analysis Completed
MS5 - Thesis Submitted and Defended
MS6 - Thesis Revised, Final Submission

Figure 18: Thesis Timeline

5.5. Reliability and Limitations

This section elaborates on the reliability and limitations of this research.

5.5.1. Language and Translation Related Limitations

English and German publications were reviewed in the literature review, as most academic research is disseminated in English (Rao, 2018). It is possible that some research published in other languages may have been missed. One interview was conducted in English and five in German. A single translator was used to minimize the potential impact of translation on the analysis, as advised in Twinn (1997).

5.5.2. Interview Sample Size and Sampling Bias

The small interview sample size of six and the use of convenience sampling pose potential risks to the reliability of the research results. Convenience sampling is prone to bias, generates results lacking generalizability as recruitment of a diverse sample is difficult and often causes self-selection bias.

5.5.3. Narrow Geographical Focus

This study focused on private pilot training in Switzerland. While aviation is subject to international standardization, there are risks involved in studies with a narrow geographical focus, such as limited generalizability and selection bias. The author expects the study results to be applicable to the European context but plans to expand the geographic focus in a follow-up study.

5.5.4. Time and Resource Constraints

The study was conducted within six months and the author was employed full-time during the research, which required disciplined time management. Moreover, the research did not receive external funding, which made the BAK textbook analysis challenging, as it needed to be manually digitized and OCR'ed.

5.6. Ethical Considerations

The *European Code of Conduct for Research Integrity* prescribes four fundamental principles for good and ethical research practice (All European Academies, 2017) to which this research adhered:

- **Reliability** in safeguarding the quality of the research (design, method, analysis, resources).
- **Honesty** in developing, implementing and scrutinizing research, and in reporting and informing others about research in an open, fair, complete and objective way.
- **Respect** for colleagues, participants, society, ecosystems, cultural heritage and the environment.
- **Accountability** for research from idea to publication, for management and organization, for education, supervision and mentorship, and for their wider consequences.

This study did not involve ethically sensitive topics or vulnerable groups. The qualitative interviews involved no minors or vulnerable groups, and written consent was obtained via a Participant Consent Form (see *Appendix 5: Interview Participant Consent Form*) from all participants prior to participation. The participants were informed about the nature and purpose of the study and their rights to opt out, not answer questions, withdraw consent, and guaranteed anonymity. This is key to ethical research, especially qualitative research (Orb et al., 2001; Vetenskapsrådet, 2017).

Convenience sampling may raise ethical concerns if researchers select participants who are easily accessible or known to them, such as friends or colleagues, which may result in conflicts of interest or breaches of confidentiality. The author estimates this effect to be small in the context of this thesis, despite being acquainted with some of the interviewees. In compliance with the ethical research guidelines in Vetenskapsrådet (2017), names of interviewees as well as name references to persons related to or located within the circle of acquaintances of either the interviewee or the author were changed or anonymized to avoid any inference to peoples' concrete identities.

6. Results

This chapter presents the results from the document and interview analyses.

6.1. Document Analysis of PPL(A) Learning Material

Coding the documents, it showed that the chosen aspects, or parts of it, were in fact reflected in GuV, but only in five of the nine theory subjects of the BAK textbook. The respective chapters in the BAK textbook were 010 – Recht der Luftfahrt (Air Law), 020 – Luftfahrzeugkenntnisse (Aircraft General Knowledge), 030 – Flugleistungen und Flugplanungen (Flight Performance & Planning), 040 – Menschliches Leistungsvermögen (Human Performance), 090 – Kommunikation (Communications) (overview in *Figure 19*).

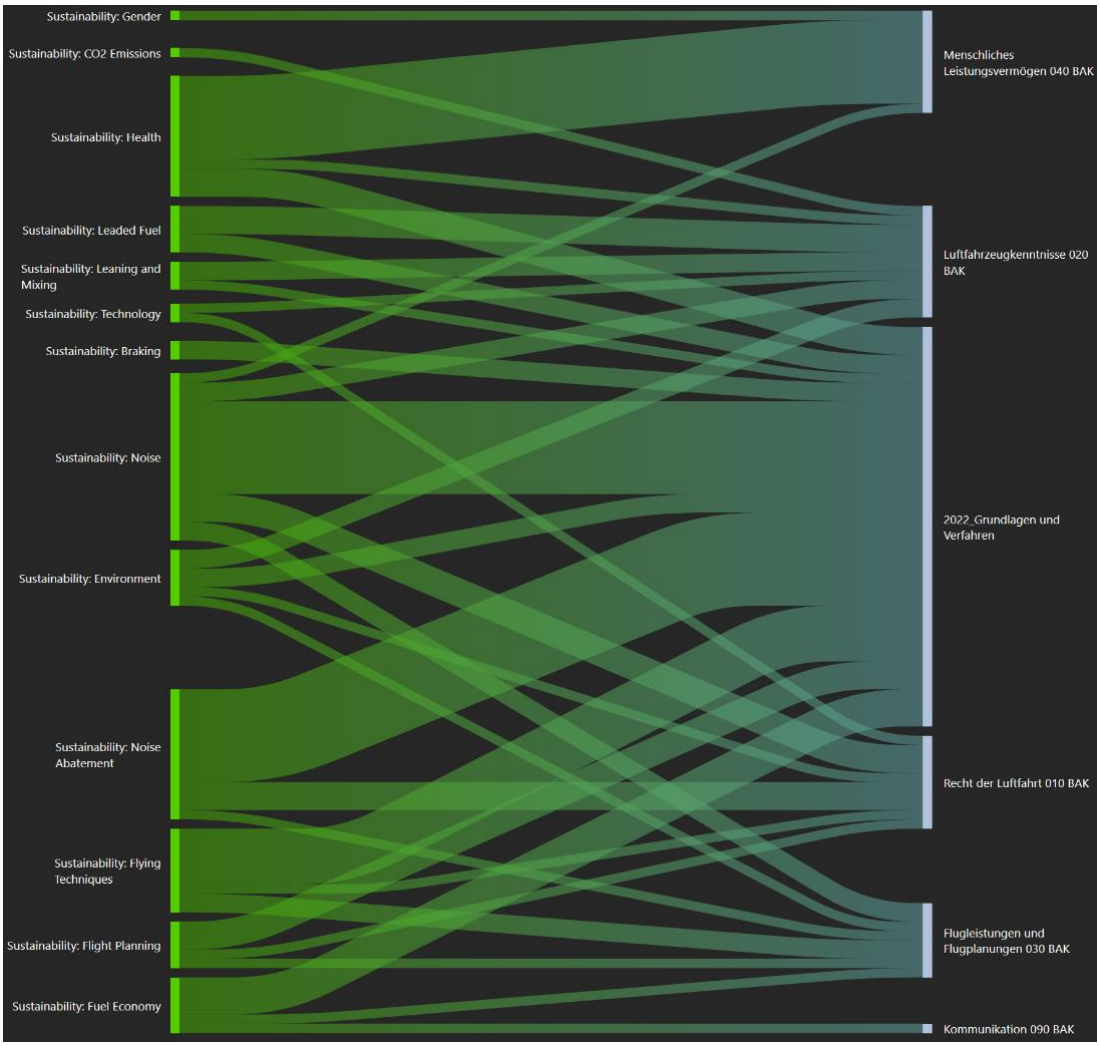


Figure 19: Subcode Frequencies in Analyzed PPL(A) Learning Material

6.1.1. Sustainability and Sustainable Development

The analysis showed that sustainability aspects, even if just marginally, are indeed addressed in the analyzed PPL(A) learning material. The most prominent codes were related to 1) noise, 2) noise abatement, 2) health, 3) flying techniques, 4) environment, 5) fuel economy, and 6) flight planning, which can also be seen in the visualization in *Figure 20*. All quotes in this section and its subsections are literal translations from the German original.

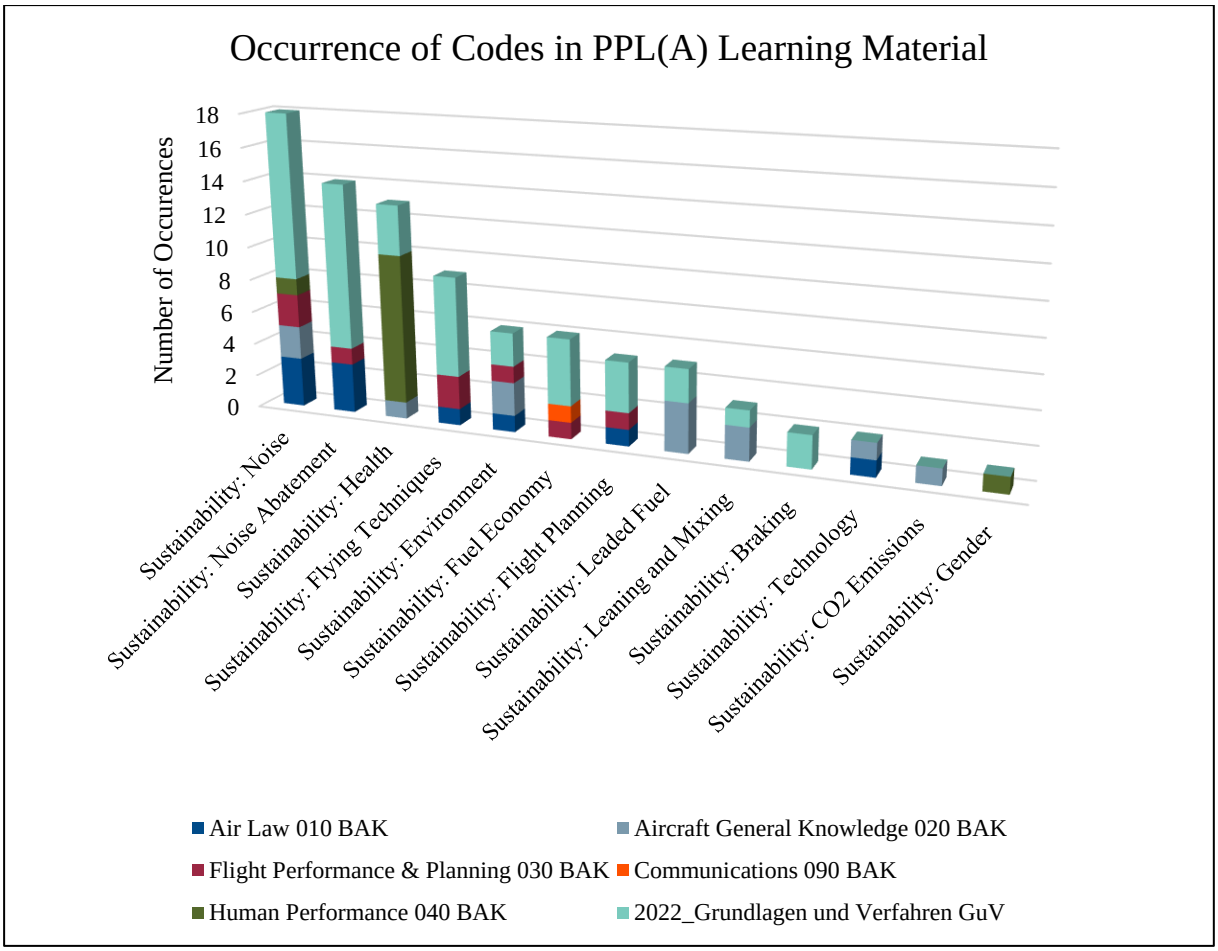


Figure 20: Occurrences of Sustainability Codes in PPL(A) Learning Material

6.1.1.1. Noise and Noise Abatement

Aviation noise is a highly important social sustainability problem in Switzerland, and were by far the most addressed sustainability-related topics in the analyzed PPL(A) learning material. In *Figure 21*, it can be seen that the two codes “Noise” and “Noise Abatement” are addressed mostly in GuV. Since the two codes are interrelated, this section analyzes both.

An important paragraph in Air Law (Subject 010 BAK) was that "[a]n aircraft may only cause noise to the extent that it is unavoidable with responsible behavior and proper operation". Besides further technical explanations, for instance about the functioning of silencers in aircraft exhaust systems (Aircraft General Knowledge 020 BAK), or the noise distribution advantage of approach and departure sectors (instead of fixed points) (Flight Performance & Planning 030 BAK), GuV, which addresses the noise topic the most, gives concrete advice abate noise by using respectful behavior towards larger airplanes not to force them to unnecessarily stop and having to start taxiing again.

Furthermore, GuV urges pilots to respect noise sensitive areas, not to fly with full flaps longer than necessary, not to brake while using increased engine power, and to fly with reduced power near ground to abate noise. Also, GuV recommends pilots to always choose the shortest approach route possible, and to use as much of the runway as possible during takeoff because it "(..) reduces the noise generated during low overflights of areas close to the airfield". Lastly, an important dimension of noise abatement is mentioned in GuV to ongoing pilots as it speaks of "political flying" which refers to the avoidance of noise in the vicinity of airfields and the situation that "(..) airfield operators are increasingly forced to use local procedures".

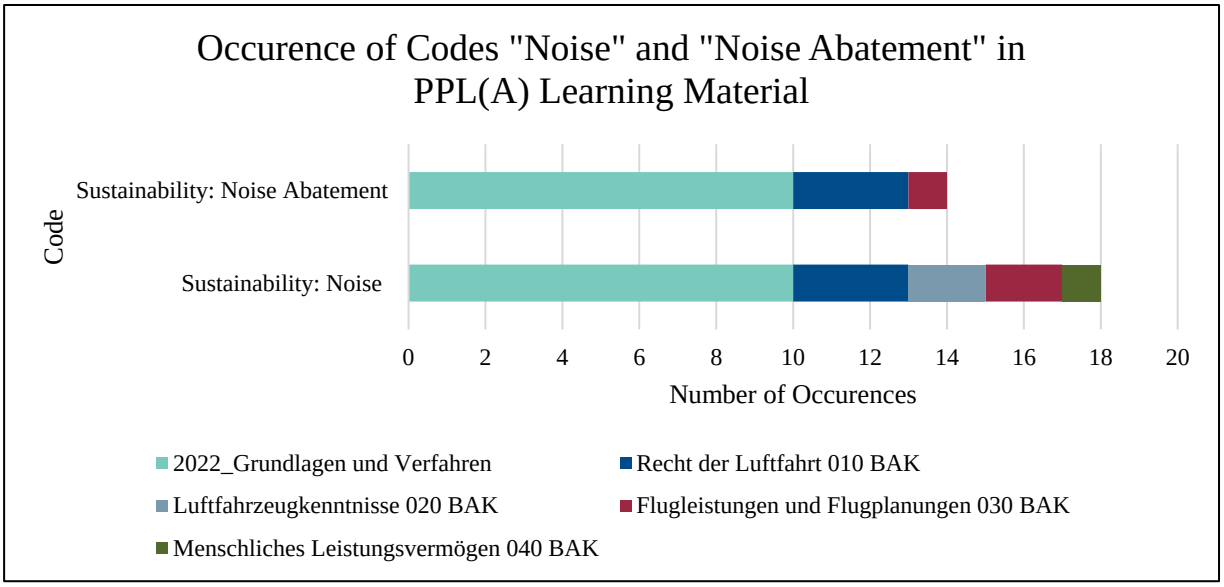


Figure 21: Code Occurrence of "Noise" and "Noise Abatement" in PPL(A) Learning Material

6.1.1.2. Health

Health, touching particularly upon the social pillar, is an important topic within sustainability and sustainable development (SDG 3 – "Good Health and Wellbeing"), and plays an essential role in aviation as well as for aviators. Thus, the topic is addressed in PPL(A) learning material where the analysis showed that, unsurprisingly, the topic is foremost addressed in BAK 040 (Human Performance). GuV addresses the topic as well. The code occurrence can be seen in *Figure 22*.

The dominant way of how the topic is addressed in both BAK and GuV, is to warn ongoing pilots of dangers from, e.g., skin contact with leaded fuel, or inhaling carbon monoxide, fuel vapors, and coolant vapors (glycol). Furthermore, pilots are warned of the risks from having too high or too low blood pressure, obesity, high blood cholesterol levels, dangers of smoking, drug-based intoxication, fatigue, choosing too high vertical speeds (especially sinking rates), among others.

In BAK 040 there is a strong recommendation to pilots to do regular physical exercise as it " (..) reduces tension and anxiety" and "(..) can increase cognitive performance". GuV states that the basic physical requirements for flying are: good overall health, a good night's sleep, wearing of prescribed eye corrective lenses (carrying spare glasses), and smoking should not be allowed before and during the flight service (due to altitude problems).

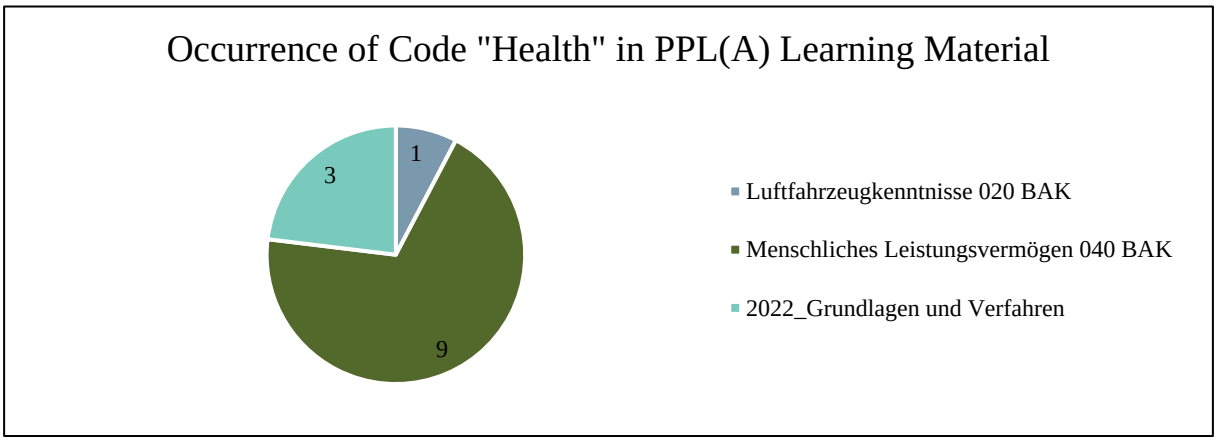


Figure 22: Code Occurrence of "Health" in PPL(A) Learning Material

6.1.1.3. Flying Techniques

Flying techniques related to sustainability aspects (noise, emissions, fuel economy etc.) were mainly addressed in GuV, and only in two of the BAK subjects, i.e., Air Law 010, and Flight Performance & Planning 030 as can be seen in *Figure 23*. Whereas most coded sections are referring to techniques to minimize noise emissions or health impacts (e.g., descending too fast), BAK 030 emphasizes that "by strictly adhering to the circuit pattern of the airfield and the procedures, the pilot makes a significant contribution to environmentally conscious flying and also to flight safety".

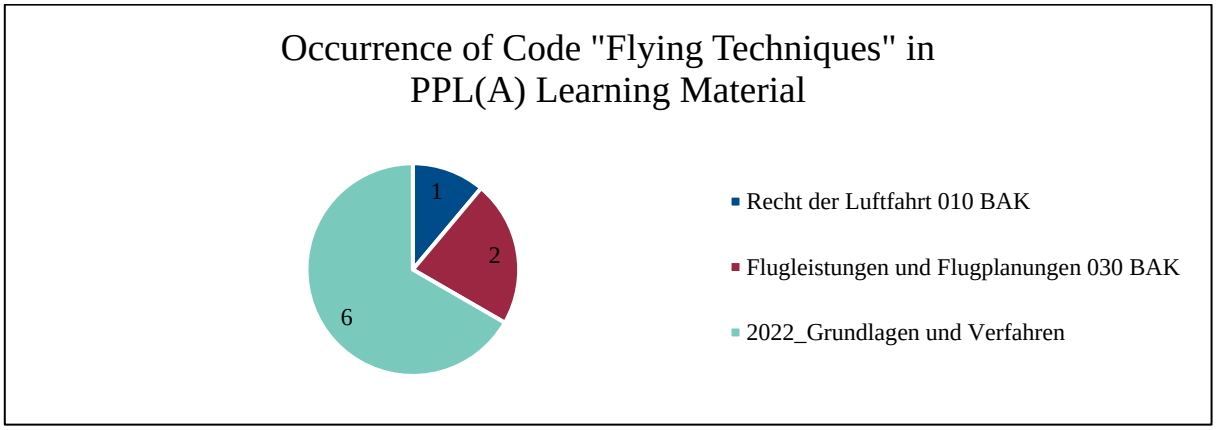


Figure 23: Code Occurrence of "Flying Techniques" in PPL(A) Learning Material

6.1.1.4. Fuel Economy

Fuel economy is an essential part of any approach to sustainable mobility. While only marginally addressed in BAK, it was foremost thematized in GuV, as can be seen in *Figure 24*. BAK 030 emphasizes that pilots should pay attention of getting bad fuel economy when taking unnecessary mass onboard. BAK 090 urges pilots to think ahead in case of much traffic and risk of delays at airfields not to wait in the plane with an idling engine because " (..) When the engine is running, fuel is consumed pointlessly, the environment is unnecessarily polluted, and at best it poses a danger to people/objects in the vicinity of the aircraft". GuV stresses the fuel economy dependence on the pilot's operations and draws an analogy to racecars:

> "[w]hether it's the shortest take-off distance, the best climb, the most economical travel or maximum speed – in the right gear, the pilot can make optimum use of his propulsion source. (..) Mistakes lead to a loss of power or even engine damage (as in the case of a racing car with a multi-speed manual transmission)"

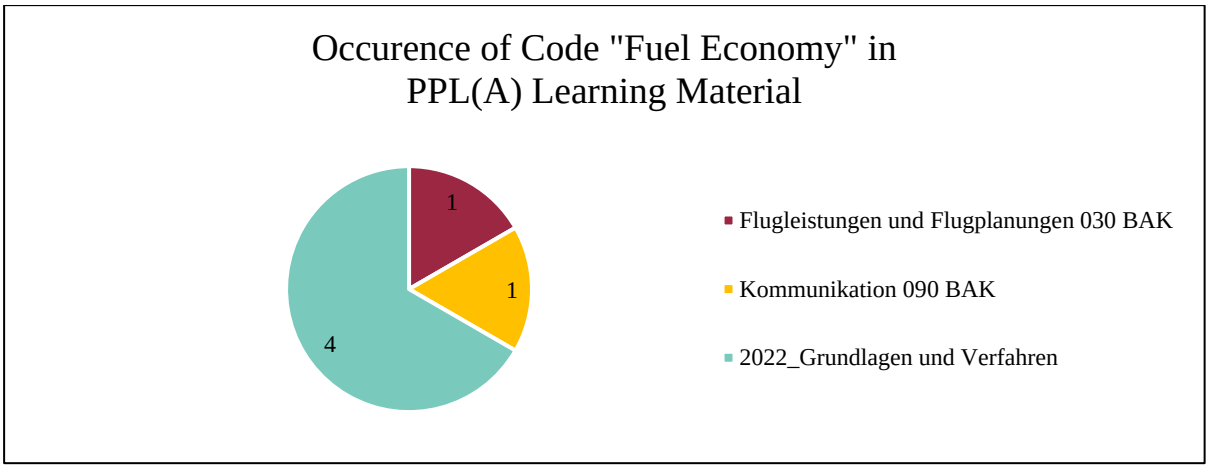


Figure 24: Code Occurrence of "Fuel Economy" in PPL(A) Learning Material

The fuel-economy-related code "Leaning and Mixing" featured two quotes in BAK 020 and one in GuV, but they only discuss the technical role of fuel mixture control, not its environmental impact or responsibility towards emissions.

6.1.1.5. Technology

The interrelation between technology and sustainability is not discussed much in the analyzed learning material. There are two occurrences in BAK (010, 020) but none in GuV. BAK 010 refers to the Aviation Information Service (AIS) and explains its purpose is "(..) to ensure the flow of aviation data and information necessary for the safety, regularity, economy and efficiency of the global air traffic management system (ATM) in a sustainable and environmentally friendly manner". BAK 020 explains the role of aircraft muffler systems and additional silencers for suppressing engine noise.

6.1.1.6. Gender

Gender issues are a social sustainability topic but were not a prevalent theme in the PPL(A) learning material, but there is one important reference in BAK 040 pointing out that "[c]hronic low blood pressure is often found in young women. Generally, it does not have a disease meaning, as it even has a positive effect on life expectancy. Exercise can raise blood pressure levels to normal levels."

6.2. Analysis of Qualitative Interviews

Using the *a priori* codes, it showed that the ten most prominent (sub-)codes measured by occurrence were: 1) Sustainability: Electric Airplane, 2) Sustainability: Issues and Challenges, 3) Practical Learning: Electric Airplane, 4) Sustainability: Fuel Economy, 5) Sustainability: Noise, 6) Practical Teaching: Teaching Style, 7) Sustainability: Technology, 8) Sustainability: Economy, 9) Sustainability: Role in Personal Life, and 10) Practical Learning: Learning Experience. *Table 7* and *Figure 25* provide quantitative details, and *Figure 26* provides a good visual overview of the main code occurrence distribution comparing the interviews with CFIs and student pilots/recently certificated private pilots. The presentation of the themes throughout the following subsections will not follow the quantitative order in the table below but will be based on the structure of the research questions and their importance for answering those.

Table 7: Top Ten Subcodes by Occurrence in All Interviews Combined

Rank	Code: Subcode	Occurrences (Absolute)	Occurences (Relative)
1	Sustainability: Electric Airplane	25	4.93%
2	Sustainability: Issues and Challenges	20	3.94%
3	Practical Learning: Electric Airplane	17	3.35%
4	Sustainability: Fuel Economy	16	3.16%
5	Sustainability: Noise	16	3.16%
6	Practical Teaching: Teaching Style	15	2.96%
7	Sustainability: Technology	15	2.96%
8	Sustainability: Economy	14	2.76%
9	Sustainability: Role in Personal Life	13	2.56%
10	Practical Learning: Learning Experience	12	2.37%

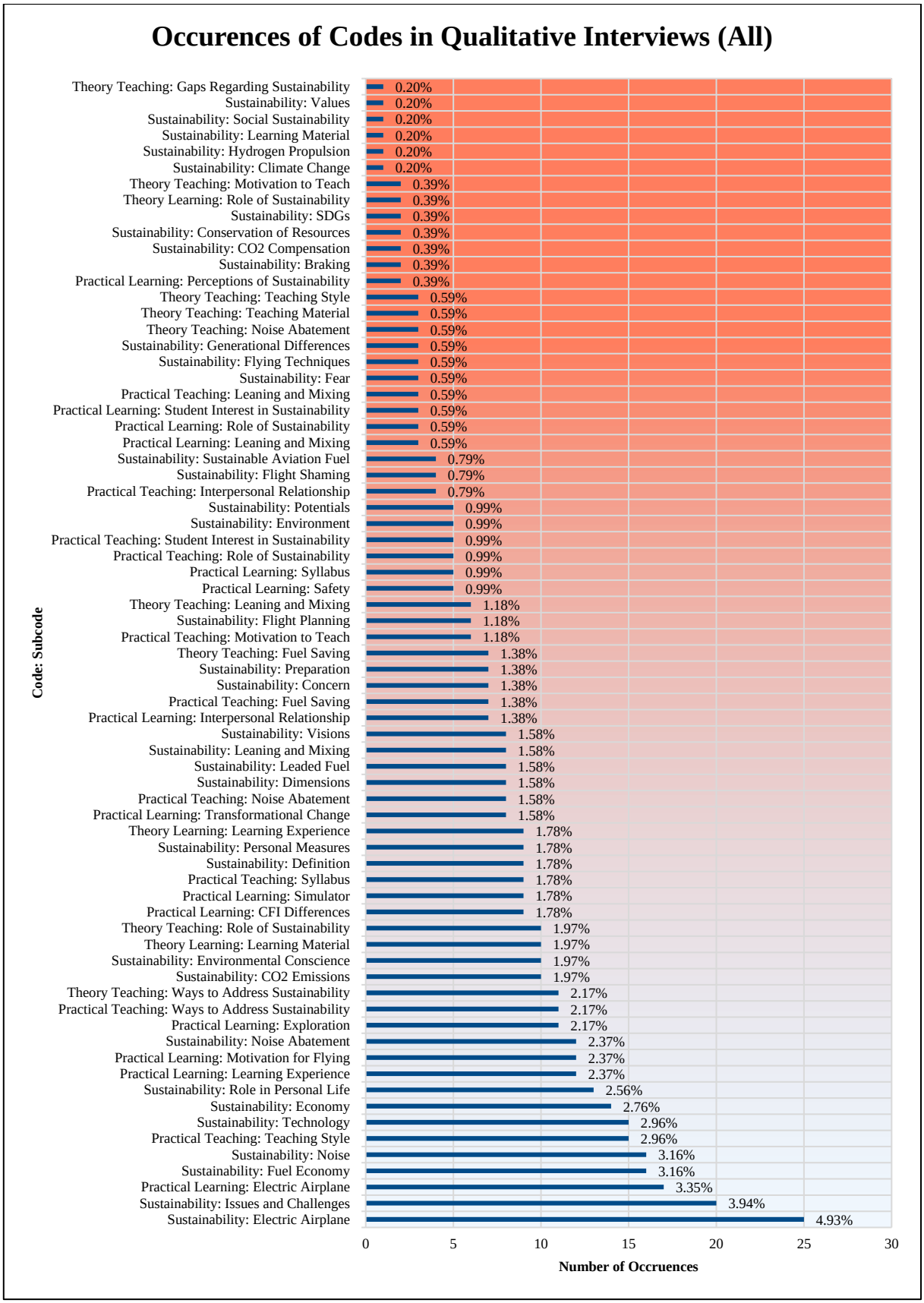


Figure 25: Subcode Occurences in All Qualitative Interviews

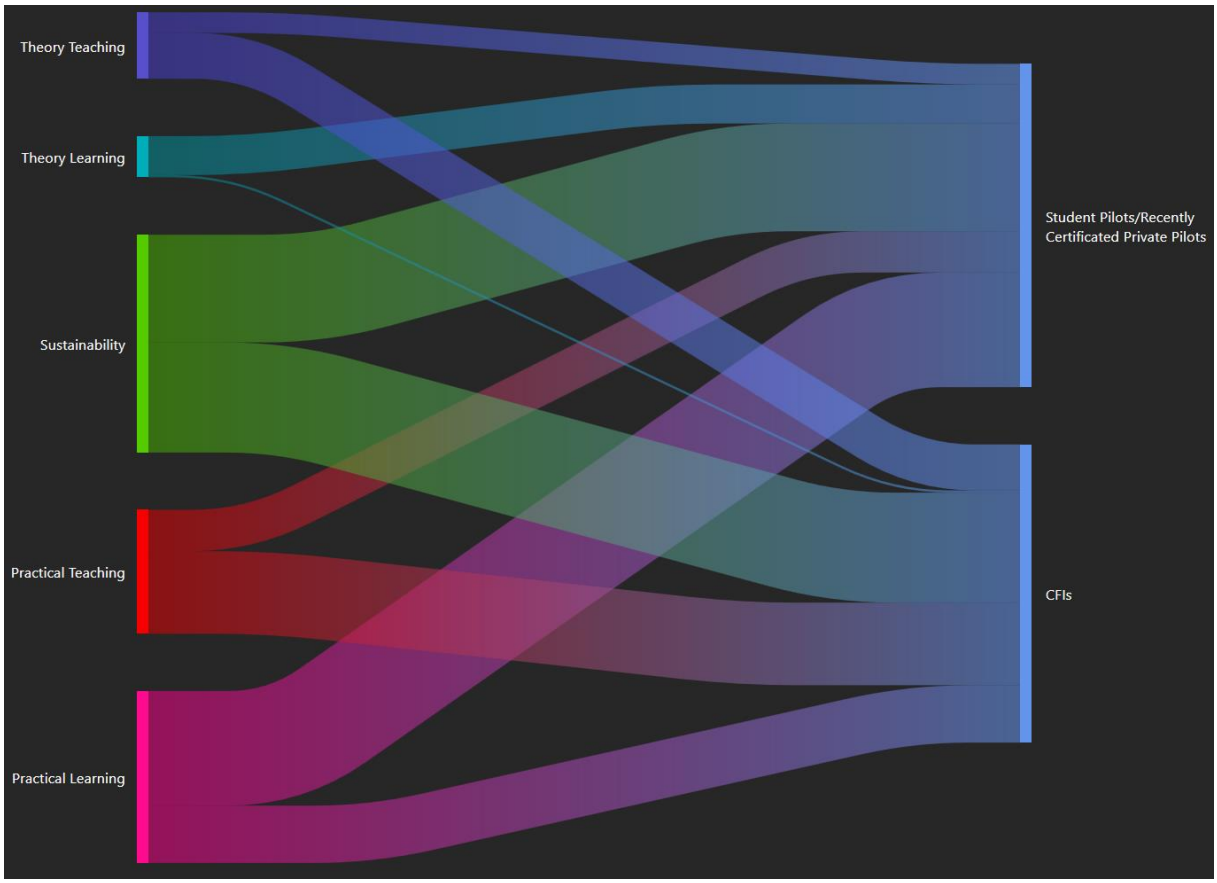


Figure 26: Main Code Occurrences in Interviews with CFIs and Student Pilots/Recently Certificated Private Pilots

6.2.1. Sustainability Definitions

As addressed in Chapter 2, the concept of sustainability has become highly ambiguous and fuzzy. Thus, it was of utmost importance to obtain the interviewees' personal definitions of sustainability to put the interview answers and the participants' reflections into context. While some interviewees struggled or took several attempts to define the concept of sustainability, some had a very clear personal definition and strong standpoint. For instance, Interviewee 4 constructed his sustainability definition around recycling, and argued as follows:

> "Defining sustainability... I have to think... Sustainability... Good question! (..) Sustainability. I think sustainability is when you have a product and from the product there is a waste product. And if you can still make something out of the waste product. Then that's sustainable, isn't it? If you now relate that to aviation. Yes, the whole story with Sustainable Aviation Fuel. I don't know either. So if you fly with frying oil or

> something. So something that has already fulfilled a benefit, if you can draw a secondary benefit from it again."

The student pilot (Interviewee 3) emphasized durability and the temporal dimension of sustainability stating that "sustainability means that something is not so short-lived that it has a long-term effect in a positive sense".

While the statements above related mostly to avoiding waste and product durability, Interviewee 2, put an emphasis on the economic pillar saying:

> "[s]ustainability is two things for me. On the one hand ecological sustainability and on the other hand I combine it with economic sustainability. (..) In other words, sustainable in the sense of 'I save something so that I have something later'. Or I think strategically now so that I have fewer problems later. For me, this is sustainable thinking."

Interviewee 5, a CFI, extensively elaborated on sustainability stating at first that it is:

> "[t]he certainty that I have done enough to be able to live here on this earth. (..) it's really the consciousness of how I stand in this reality. (..) So, of course, sustainability is also for future generations to exist, but... At the moment, it's such a term that really gets into this paralysis, especially when you say 'I have to do it this way now and I have to question everything'. Of course, I question a lot of things. But it has to be okay for me in the end."

Interviewee 5 added later as he first provided "a rather vague answer" and explained:

> "Of course, you could make this much more concrete and just make a CO_2 footprint or look at other aspects. (..) The issue of sustainability is a big issue. Especially if you take the topic of climate change (..) but there are also other points, such as poverty, life underwater, etc. Is that also in there? Is that even necessary? Is this just one issue?"

In a shorter fashion and emphasizing the avoidance of waste and economic aspects, another CFI (Interviewee 6), defined sustainability as "(..) certainly something that is future-proof. (..) you use resources so wisely that it is not wasteful. In other words, that somehow an efficient use of funds follows according to the purpose".

Congruently, Interviewee 1, also a CFI, said that "[s]ustainability is to make use of the resources in a way that you can keep using them forever. (..) you have resources and you put them in, and somehow the loop is closed and is self-sustained forever."

6.2.2. Sustainability Concerns, Challenges and Issues

This section summarizes results related to the codes “Sustainability: Concern” and “Sustainability: Issues and Challenges”.

Interviewee 3 approaches sustainability in a pragmatic way looking for ways to simplify or connect things so that he has more of them. He added that he usually does not think about sustainability very often, yet expressed his concerns:

> “It's a political trend to look at sustainability because of the environmental problems that exist. But I am concerned that there could be a lot more regulations and paperwork and that the costs for private pilots could also rise immensely. The new technologies are very expensive and the private pilots have to pay for that later.”

The former student pilot, Interviewee 2, stated the biggest challenge in private pilot training would be “(..) the high CO_2 emissions that we generate. But in percentage terms, it's not that much. However, it is already more than normal per capita, or what you should emit per capita. I don't want to sugarcoat that.”

Interviewee 2 advocated for pilots to develop a profound environmental awareness pertaining to their aviation activities: “I do think that everyone who flies and is also responsible for CO_2 emissions should be aware of what they are doing. Just to have your own opinion.”

Furthermore, Interviewee 2 pointed to the importance of awareness and social responsibility of pilots arguing that “[t[he ulterior motive of this is that we have a great hobby and want to keep it and thus do not want to annoy people”

Nevertheless, sustainability reportedly played a substantial role in the lives of two interviewed CFIs. For instance, Interviewee 1 explained:

> “I have compromises. I see myself as a “green person”. So I do my recycling, I do my sustainability thing but I fly a Gulfstream to move very few people from A to B. I burn tons of kerosene. Yeah, we all have contradictions. I love to have people involved in aviation and more pilots in it. So this is really not in the direction of sustainability. But when I fly I try to reduce the fuel consumption as much as possible, I try to reduce the noise as much as possible, I try to use the brakes as little as possible so the tires last longer. So I try to take care of those little things that can help. Aviation in itself, to make tons of metal fly is not a sustainable business in itself, of course.”

Interviewee 5 responded that sustainability plays a central role in his life:

> "(..) It's almost an obsession. Only if I drink a cup of coffee, then I bring the idea of sustainability into it. I have the strategy for myself that the topic is important, but at the same time I want to appreciate life, be grateful and do my best and take sustainability with me."

6.2.3. Sustainability Generational Differences

Throughout the researcher's experience in inquiring sustainability issues in GA, he noticed a trend that many stakeholders emphasized that younger generations are not as interested and concerned about sustainability in aviation than the older pilot generations. The results in this section correspond to the sections coded with "Sustainability: Generational Differences".

All interviewed CFIs stated that they think younger generations are less concerned about sustainability than older pilots. For instance, Interviewee 1 elaborated:

> "In younger generations in general, what I see is, that the young pilots, the ones that I have, really don't think much about sustainability. We really don't have young 'green' pilots. The ones that are really more concerned about sustainability both economically and environmental resources they are not coming to train PPL(A). The ones that want to be pilots they love the smell of kerosene and AVGAS and they want to fly."

He further explained "(..) when you talk to old pilots or people with experience, they are the ones taking care (..) of the airplanes the best. The young generations they don't even think about it". His experience showed that there is a small percentage of student pilots that want to do more training on electric airplanes, "[b]ut those are usually Tesla drivers and people that see the world in a different way".

Interviewee 6 had a similar impression but pointed out that resourceful behavior in younger pilots is mostly driven by economic concerns and often limited financial means so that they try to avoid using expensive planes, longer flights than necessary and for flights with external landings, airfields and airports with high landing fees.

Interviewee 5 increasingly observed a small share of young people so concerned about sustainability that "[i]t's overwhelming. They can't get out of it. They are so rigid in fear that they are paralyzed". However, he remarked that this is rather a minority of young people and explained:

> "As a rule, it is already the case that the young ones who start to fly, so that's an assessment, 20-30% have the topic of sustainability really present. For the elderly, the ratio is more like 40% : 60%. But that's only estimated."

6.2.4. Sustainability Gaps and Potentials

This section summarizes findings related to the codes "Theory Teaching: Gaps Regarding Sustainability", and "Sustainability: Potentials".

Some of the interviewees saw gaps that could potentially be addressed in the future. Interviewee 6 stated it is difficult to "(..) see where it would make sense to optimize something like this in the hobby business" and added that sustainability is "a very difficult topic related to PPL training". Nevertheless, he acknowledged that "[i]t is an issue that will become important in the future, but it is currently not in the foreground". Interviewee 3 argued "[y]es, you could address it and present the new solutions and the environmental problems, so that you already have a little idea of it. But at the end of the day, (..) you have to pass the theory exam".

Interviewee 1 presented critical views on addressing and potentials of addressing sustainability in PPL(A) training:

> "To tell the truth… I mean sustainability or the things you can teach they are gonna affect the environment by a percentage of 5 to 10 percent maximum. I don't think we are gonna improve it like 50% or something that is on a level of magnitude. So, yes we could include a 10 or 20 percent more in direction of sustainability, but I will say not so much in the resources but more in the direction of noise."

Interviewee 1 concluded "(..) So, yeah, I think from my perspective compared to the rest of the world, it's already pretty good in Switzerland. And I wouldn't add a lot more on sustainability"

Interviewee 5 saw gaps and potential in addressing sustainability more in PPL(A) training, for instance in the syllabus, but pointed out that they "(..) need a consensus in the group of trainers" and argued:

> "(..) it would need something like common values. That would have to be written down. I'm currently trying to define what our flight school is all about, what our values are and where we want to go in the future. One of the points is also that we focus more on sustainability awareness."

6.2.5. Role of Sustainability in Learning and Teaching

The results in this section relate to the codes “Practical Learning: Role of Sustainability”, “Practical Teaching: Role of Sustainability”, “Theory Learning: Role of Sustainability”, “Theory Teaching: Role of Sustainability” and capture thus perspectives of student pilots as well as instructors.

The interviewees were asked about their perception of the role and representation of sustainability in PPL(A) theory pertaining to both perspectives, learning and teaching.

Interviewee 3 did not see sustainability issues taught to any substantial degree in PPL(A) theory lessons:

> “(..) sustainability issues were not really an aspect in theory. I don't remember anything being dealt with in the direction of sustainability. Although, but perhaps in terms of drive technologies. The electric drives were presented in comparison to the combustion engines.”

Interviewee 2 reflected upon his theory learning experience and similarly concluded that sustainability was sometimes addressed but not a prominent theme in theory lessons pointing that there were differences between the theory instructors and their foci. However, he added that not every subject has the potential to address sustainability equally and argued that “(..) it's not the job of an air law teacher to educate us about sustainability”. Interviewee 4 did not see sustainability issues addressed in his PPL(A) theory learning process.

One of the interviewed CFIs (Interviewee 6), being a theory instructor as well, admitted that he addresses sustainability “[r]elatively little, actually” yet further explained that the room for addressing it “(..) is not so great. I have the feeling that those who do this do it as a hobby. The hobby is not primarily about efficiency but about fun”. He still stressed that students should learn to adjust the fuel mixture right at all times and only take as much fuel as possible to fly fuel-efficiently but moderated this by arguing that “(..) this is not so relevant in our aviation sector and is simply not so central”.

Interviewee 1, a CFI articulated that in terms of sustainability in PPL(A) theory, instructors should explain things about fuel consumption for example, leaning the mixture, knowing what to do with the engine, not over accelerating things with the RPMs of the of the aircraft, the correct use of flaps on approaches, you know configuration of the aircraft. In his opinion “we can all take small steps on the sustainability there, also when you plan a route” yet opposed that “(..) in the private pilot life most of the time you fly as a hobby and you fly because you want to fly e.g. to see the Matterhorn. It’s not like in your commercial life where everything is measured to the minimum”.

Interviewee 5 admitted that he addresses sustainability in practical flight training “[u]nfortunately too little and only on demand” explaining that it very much depends on the respective flight student and

their personal interest in sustainability topics. He reported that "[he] had a student pilot with whom [he] often had discussions about the topic", especially CO_2 emissions and compensation.

On the other hand, Interviewee 6 did "(..) not think it's such a big issue at PPL level because there's a hobby behind it. In CPL training, this is more of an issue. It's all about costs and fuel consumption". Nevertheless, he stressed that there are indirect sustainability concerns in practical training and student pilots depending on their financial situation if he is for instance still a student or apprentice so that "(..) he takes a closer look at everything that costs money, (..) flight time, airports, landing fees and so on. You can tell that there is more pressure there. (..) this is not directly because of sustainability".

6.2.6. Obstacles and Ways to Address Sustainability in PPL(A) Training

This section presents results linked to the codes "Practical Learning: Obstacles to Sustainability", "Practical Teaching: Ways to Address Sustainability", and "Theory Teaching: Ways to Address Sustainability"

Different perspectives and perceptions regarding the largest challenges to sustainability in PPL(A) training emerged in the interview answers. First, the students'/recently certificated private pilots' views will be presented, followed by the CFI point of view.

For instance, Interviewee 4 addressed the current limitations and challenges involved in using electric planes and said:

> "I mean (..) they have already implemented it well so that you can make the first flight lessons with the Velis. That's fine. But you can't go on with it afterwards. One is limited by the limited range. The plane runs out of juice quite quickly compared to a gasoline engine. That's quite a challenge."

Interviewee 3, on the other hand, addressed the challenges noise and leaded fuel use by stating that he would like to use unleaded gasoline as "[i]t would make everything easier and cheaper". Nevertheless, bureaucracy is a major challenge as well: "Of course, it is also a paper problem". He acknowledged that noise may be a sustainability challenge, yet not to everyone: "I personally don't worry about it at all. Logically, I understand that certain people who live at the airport don't like it. Personally, however, I would be delighted".

Although Interviewee 2 thought that GA "(..) tends to go in the right direction", it still lacks "a fundamental solution". He explained that "[j]ust because the planes fly electrically, we still haven't

solved the lithium problem. I'm not an expert, but I see from my perspective (..) that the whole thing is a dilemma". In addition, he elaborated on problem of the aging aircraft fleet: "We fly with airplanes from the 1920s and 1950s ourselves. We would have to buy new aircraft, then it would also become more ecological. But the old planes are just too good, they just don't break."

Although flight shaming did reportedly not seem to have affected Interviewees 3 and 4, Interviewee 2 experienced it as a major challenge and argued:

> "Whenever I talked to someone and said I would get a pilot's license, I always said 'hey, but I also fly electrically'. (..) I have to say, I also think it's cool to fly electrically. I just don't have that many mega green friends. There are a few acquaintances who are on the green eco-track. I don't like to talk to them about it, not even about my work, because I know it's a grey area."

After pointing to the major challenge of leaded AVGAS, Interviewee 5 stated that further challenges include fleet policies and organizational decision-making in flight schools and explained: "This is political. The student pilot has not much to say. At the moment we have a bit of discussion about buying a second two-seater. (..) That would be the challenge to find a consensus between different opinions of the flight school, the flight operations group and so on". He also saw challenges rooted in the still inflexible PPL(A) syllabus that does not incentivize simulator training: "We can save fuel and noise. We are not yet fully exploiting our potential". He continued and argued "(..) one problem with the simulator is that the flight instructor doesn't get paid and you can't log the lessons".

Interviewee 6 saw several challenges to sustainability in PPL(A) training, the biggest challenge for him were the dated "AVGAS engines from the 1960s or 1970s, which are practically unchanged in technology to this day."

The topic of noise was emphasized in the context of Switzerland's population density:

> "(..) This means that airfields are not 5km away from populated areas, but very often in inhabited areas. (..) As flight instructors, we hear this all the time and also point it out to our students and make sure that the circuit geometry is flown properly".

Having substantial experience with training students on the electric plane, Interviewee 6 stressed that "[w]hen it comes to electric drive, range is always the issue. You have to be very careful with the current state of technology, i.e. with the energy and with the performance". Furthermore, he also saw a major challenge for PPL(A) training arguing that "(..) if the fuel issue becomes even more important and urgent, I can imagine that this might not be possible anymore. It may be that this is no longer acceptable from the social or cost conditions". Lastly, he argued that sustainability in general "(..) is a very difficult

topic related to PPL education. I would say it's not such an urgent topic in PPL education. It is still difficult to find starting points anywhere."

Interviewee 1 pointed out space issues and related noise problems which lead to adverse pressure on GA, and argued "(..) the agglomerations are growing more and more. So that's a part on the sustainability, let's say external factors from people that don't want us to keep flying."

He further addressed the leaded aviation gasoline problem and speculated that "[t]he way I see the future regarding sustainability is that AVGAS is banned in the next years and we will go for all-electrical airplanes for private pilot training but I really don't know what the future will look like". Also making a comparison to the automotive industry, Interviewee 1 explained: "If everybody goes electric on the cars, then they want us to go all-electric with the planes.(..). We don't know what we are gonna have, and the noise is always going to be there."

6.2.7. Sustainability Visions

The answers presented in this section relate to the code "Sustainability: Visions" and present the interviewees' visions of fully sustainable PPL(A) training. First the views of the student pilots/recently certificated private pilots will be presented, followed by CFI perspectives. Noticeably, all of their visions included the use of electric planes.

Interviewee 2 provided a detailed vision:

> "Electric planes only. Firstly, this. I think, for example, that the powered flight group Pilatus said that we make the first flight lessons until the first solo flight on the electric aircraft, is mega cool. No emissions and it is enough for circuit training. 40 minutes flight time and one hour recharge and then each 40 minutes flight time. That's enough. Even if it had nothing to do with ecology, it would be a best way to train pilots. If you've never been on a plane before... You just press four buttons and then this machine runs. Finito."

Interviewee 3 argued "[f]rom an environmental point of view, it would be important to use newer aircraft and rely on new technologies. The Velis, for example, is electric. Of course, this also depends on costs".

Concurrently, Interviewee 4 stated he "(..) would do everything with the Velis immediately. It is also much cheaper. (..)I would make the PPL purely electric. I think it would be cool if you could do the PPL completely with the Velis and zero emissions."

The following paragraphs will present the views and perspectives of the CFIs. Interviewee 1 had a vision of more sustainable PPL(A) training, and having originally started with a glider license (GPL), he suggested that one could learn the first 10 hours of flying on gliders while "(..) you don't need to be towed all the time, you could use a winch, so you can take off with a cable and that's completely sustainable" .

He further suggested:

> "You could do another 10 hours with an electric airplane to really see what is the effect of the engine, of the propeller.. so I mean you have out of the syllabus of 45 hours of a PPL, 10 hours in a glider and 10 in an electric plane, you will already cut by half the part of the fuel burning".

Interviewee 1 added:

> "(..) If they are willing to inject a bit more money in the schools, then we could have much more efficient engines, like it happens in commercial aviation. In commercial aviation, every decade you reduce the fuel consumption by half. And we are flying machines from the 60s… so yes, very robust (..) but they burn fuel like hell."

Interviewee 5 explained his plans to put a larger emphasis on sustainability in flight training arguing it is important "(..) to bring this sustainability idea into the flight instructor community. That's where it has to start! (..) But we should also see if we should include it in web-based training". He explained:

> "I would like it to be a 'beam' that runs throughout the entire training. In part, it is our job to address this issue. But it is not our job to explain the basics like the UN SDGs etc. I myself have some moral conflicts. If so, however, sustainability would have to be addressed during the initial discussion. One could point out possibilities of compensation and ask what is wanted. You could also make a monitor program."

Furthermore, he suggested creating and communicating a sustainability ethos and said "We can then also write this on our website. I mean, we have already made that quite strong regarding the Velis. I think that was quite well received by the flight students". Focusing more on the practical side of PPL(A) training he imagined:

> "Levels 1 to 4 purely electric. And then for cross-country flights, an identical model with an economical engine. Fly with an e-fuel[11] or SAF at some point. (..) So at the beginning electrically and then with e-fuel or SAF. Then I would look at how the simulator can be integrated more into the training. (..) I think electric, SAF, e-fuels and then simulator. That's where we're going."

Interviewee 6, who has already trained four pilots on electric planes, put a strong emphasis on electric aviation in his vision:

> "(..) [T]here are many different projects with electric aircraft. So far, however, only one has made it on the market and that is the Pipistrel Velis Electro. I think there is probably not as much motivation as in the automotive industry to invest so much money there."

6.2.8. Learning Experience (Theory and Practice)

In educational experiences, it is not only important "what" but also "how" a student learns. Thus, this section presents results related to the codes "Practical Learning: Learning Experience" and "Theory Learning: Learning Experience".

The student pilot and the recently certificated private pilots used a variety of learning materials and media. All of them used the BAK textbook, two of them GuV. All of them stated to have complemented their theory learning phase by using YouTube aviation videos. Interviewee 2 added that he also used flight simulators (*X-Plane*) to complement his training. Other media included, the SPHAIR online training course, smartphone applications, as well as the e-learning platform based on the BAK textbook. Two of the students had their theory as distance learning (due to Covid-19) with theory instructors, and one as independent distance learning without theory classes, only textbooks and learning material.

Interviewee 4 who chose independent distance learning without theory lessons argued that this mode of studying met his expectations because it allowed him to work fulltime while doing the PPL(A) training. Interviewee 3 explained that because he was in the apprentice house "(..) it was not so easy. I was rarely alone and it often got loud. Then it was often the case that I had to learn a lot afterwards in self-study". Interviewee 2 liked his distance learning lessons experience (over Zoom) overall, yet argued "(..)

[11] E-Fuel = Electrofuels, a class of synthetic fuels, are a type of drop-in replacement fuel. They are manufactured using captured carbon dioxide or carbon monoxide, together with hydrogen obtained from sustainable electricity sources such as wind, solar and nuclear power. (see e.g., https://en.wikipedia.org/wiki/Electrofuel)

sometimes it was boring. But there were only a few days when I said 'I'm not interested'. Otherwise it was mega cool". After each lesson was over, he recalled:

> "[W]e also drank and looked at PPL theory. (..) [w]e watched two or three hours of airplane videos on YouTube. That was mega cool. Time has flown by so quickly. You had two appointments every week and then the voice lessons... Time has passed so fast"

6.2.9. Transformative Learning

One important question to the interviewees was whether and how their views on sustainability have changed over the course of their PPL(A) training. The section summarizes findings related to the codes "Practical Learning: Transformational Change" and "Practical Learning: Exploration".

While Interviewee 2 and Interviewee 3 stated that their sustainability views have not changed throughout their PPL(A) training, Interviewee 4, expanded on a few more details:

> "No, unfortunately not much has changed. Unfortunately, I didn't know that before about electric flying. I think it's a cool thing and I'm convinced of it. (..) Then I think the Sustainable Aviation Fuel thing is great if it could be developed further. (..) I just didn't have all that on my radar before."

Furthermore, Interviewees 2, 3 and 4 were asked about how they experienced the learning process and how they explored flying for themselves. Interviewee 4 felt that he was able to discover and explore flying on his own to a certain extent yet added it was not always the case as "there are things that you just have to learn". Similarly, Interviewee 3 argued that there are certain learning processes that are part of the program and that you just have to go through: "(..) but it also varies from flight instructor to flight instructor. (..) [S]ometimes, you can also bring in your own things. (..) It has never been a rigid construct of learning phases. It was very individual".

Interviewee 2 expanded on his practical discovery process: "I don't know. I was just like you flight simmer[12]. For me, the flight school was only a means to an end. There was nothing new about flying, which I discovered then". Yet, he also argued he would have liked a bit more freedom granted by the CFIs to play around and discover flight for himself:

[12] Flight simmer = a person playing flight simulators on PC or game consoles

> “I thought to myself ‘let me fail, let me fall on my face so that I can feel what the plane can do’. That's what I learned. But sometimes you have to open your mouth. Then the flight lesson may not be successful, but you get a feel for the plane”.

The CFIs also uttered their perspectives. Interviewee 1 elaborated:

> “For me, the briefing and the debriefing is very important. So if we have a good plan in the briefing, then later in the debriefing I can ask the students questions so he can discover himself what was good and was not so good. And at the end it is important that he is motivated for the next step. I never tell them what was really bad. He has to discover it and realize.”

He furthermore pointed out the importance of raising awareness in students and argued “(..) it’s a self-discovery process” stating:

> “I am not very strict as an instructor. I just give a path for the student to realize what he has to and where he has to improve. You may say I am too easy. But in reality it’s not so easy. The pilot needs to discover it by himself.”

Interviewee 5 said that his teaching is about “(..) motivating and activating this person, so that he comes into independence”. While he stated that “[t]he flight students should discover flying”, he questioned “(..) if that's the right way to go. (..) Maybe it's not quite efficient that I first show something and then let the student pilot imitate, but I believe that again concerns the interpersonal. I need to understand how the person works”.

6.3. Answers to the Research Questions

This section provides answers to the research questions based on the results that were presented throughout the preceding two subsections.

6.3.1. RQ1 – Teaching and Gaps in Teaching about Sustainability and SD

The document analyses revealed that issues related to sustainability and SD were only marginally taught in PPL(A) learning material commonly used in Switzerland. While in the practical syllabus-oriented learning material GuV sustainability-related topics were occasionally addressed throughout the document, sustainability-related issues were taught in only five of the nine theory subjects of the BAK textbook, i.e., 010 (Air Law), 020 (Aircraft General Knowledge), 030 (Flight Performance & Planning), 040 (Human Performance), and 090 (Communications). The main themes that emerged from the analysis concerned 1) noise emissions and noise abatement, 2) health issues, 3) flying techniques, 4) environmental issues, 5) fuel economy, and 6) flight planning. In most cases, the issues were taught from a very technical standpoint without any critical discussion or incentive for learners to critically reflect on the addressed issues. This indicates a very normative educational approach.

The interview analysis showed that issues related to sustainability and SD-related were taught in theoretical and practical PPL(A) training, if only marginally as well. Themes that dominated the results were related to electric aviation, fuel economy, and noise emissions as well as noise abatement. The student pilots/recently certificated private pilots reported that they did not see sustainability taught to any substantial extent in learning materials or theory lessons, they asserted that sustainability played a significant role in practical training, especially in the use of electric airplanes, fuel management, and noise abatement. There were significant differences in the interview answers from CFIs. While Interviewees 1 and 6 did not assign a big role to teaching sustainability in their practical instruction, Interviewee 5 claimed to address sustainability as much as possible admitting that it would still be too little at times.

Even though the interview sample size is small, a general trend can be identified, in combination with the results from the document analysis. Sustainability and SD-related issues are only slightly touched upon in PPL(A) learning material and theory lessons. They are taught in practical lessons a little more, but still only marginally. In most of the considered cases, sustainability and SD were put into relation with the environmental and social dimensions, particularly fuel consumption/economy, noise, and CO_2 emissions.

As stated before, sustainability and SD were not represented to any significant extent in PPL(A) learning material or theory lessons. The document analysis showed that whenever sustainability or SD-related issues were addressed, it was done in a normative way. Furthermore, information about the environmental impacts of GA (e.g., CO_2 contribution, global warming, health-adverse lead and bromide emissions), or other sustainability-related issues such as gender inequality, mobility injustice and privileges, etc., were lacking in the analyzed learning material. A critical discussion and stimuli for learners to critically reflect upon such issues were also absent.

The interviewees, both the group of CFIs and student pilots/recently certificated private pilots, reported that one could address sustainability a little more in theory lessons but had difficulties to say in which subjects or situations, or even doubts about whether it would have any significant impact. Interviewee 5 was a clear exception seeing many gaps pertaining to addressing sustainability and SD in theory lessons, and practical PPL(A) training suggesting that the CFI community needs a sustainability consensus, and a written set of sustainability values. His primary objective was to foster critical awareness of sustainability.

From this it can be concluded, that the underrepresentation and little discussion of sustainability and SD-related issues in learning material, theory lessons, and practical training is a major gap that leads to a limited sustainability awareness.

6.3.2. RQ2 – Transformative ESD for a Sustainability Transition in PPL(A) Training

The central element of transformative learning theory is the disorientation dilemma at the beginning of the transformational learning process in a learner (Mezirow, 2008).

The interviews with student pilots / recently certificated private pilots showed these did not really experience this dilemma under the conditions of the current PPL(A) theory and practical training, with the exception of Interviewee 2. The latter stated that he sometimes was ashamed and avoided to talk about his flight training activities when being around “green” friends as it had caused major arguments before. However, he also reported that he used his basic training using the electric airplane Pipistrel Velis Electro as an environmental justification. While the interviewees were aware of their unsustainable flight activities in terms of noise and CO_2 emissions (when flying gasoline-fueled planes), none of them experienced feelings of *flight shame* or likewise. None of the interviewees stated that their views on sustainability had fundamentally changed over the course of their PPL(A) training experience, which also indicates the absence of transformational learning in this field.

What has been addressed in the answers to RQ1 is that there needs to be more critical reflection upon the sustainability impacts of GA during the PPL(A) training phase. The abovementioned interview answers from PPL students showed that in order to facilitate transformative learning in future PPL(A) students CFIs, theory instructors and learning materials need to induce a strong initial disorienting dilemma that leads to critical self-examination and reflection on the inherent unsustainability of PPL(A) training. This should not be aimed at causing students to quit their PPL(A) training but rather become more aware of sustainability and ways to be more sustainable when flying. There are many pilot decisions that impact the overall environmental impact of flying, such as flight planning, fuel management, choosing to fly electric, fuel economic flying techniques, noise abatement techniques, among others. If these elements are not just "taught" by instructors but also critically elaborated and explained "why" one should act in a certain way, student pilots and later private pilots may be more likely to become critical of their own flying activities, which will most likely produce more sustainability-minded private pilots whose SD-oriented decision-making will increase the overall sustainability of GA.

Thus, it can be concluded that a transformative ESD approach has the potential of catalyzing more sustainable PPL(A) training and GA. However, there needs to be concerted sustainability efforts and consensus in the GA and CFI community to achieve this, starting with definitions of common values, revisions of learning materials, theory lessons, and practical flight training sessions.

7. Discussion

The results from the document analysis showed that sustainability and SD are only marginally thematized in PPL(A) learning material. While the thematization of such issues was noticeable throughout GuV, yet only five out of nine subjects in BAK, it also pertained prevalently to technological and environmental aspects related to flight planning and flying techniques that increase fuel economy (and ultimately GHG emissions), safety/health, as well as abate noise. The latter issue, i.e., noise abatement, touches especially upon the social dimension of sustainability. This corresponds with findings in Stiebe (2022) where noise emissions were identified as the main sustainability challenges in GA and PPL(A) training behind the problem of the continued use of leaded aviation gasoline. Despite being one of the most pressing problems in GA (Cloche, 2010), AVGAS 100LL and its environmental and health impacts were not critically addressed to any significant extent in the learning materials. Furthermore, the learning materials lack information and critical depictions of GHG emissions and the overall sustainability impact of PPL(A) training and GA. Since the learning materials are designed after a quite normative education approach, there is a deficiency in the learning materials pertaining to a holistic discussion, as well as absence of triggers to induce critical thinking about GA's sustainability impacts.

The interviews indicated that student pilots/recently certificated private pilots did not perceive sustainability or SD as taught to any noteworthy degree in PPL(A) theory lessons. Interviewee 3 remarked "sustainability issues were not really an aspect in theory". Interviewee 6 remarked that he addresses sustainability in his theory lessons "[r]elatively little, actually" as he sees only little room for addressing sustainability in his subject (030 Flight Performance & Planning), which is surprising since this subject was prominent in the document analysis and is inherently related to planning and decision-making that has a noteworthy impact on how fuel-, and noise-efficient a flight can be conducted.

On the other hand, the interviewees reported that sustainability had been taught to a certain extent in practical PPL(A) training lessons, mainly related to noise abatement and flying and planning techniques to increase fuel economy. It was mentioned that there are significant differences between CFIs and their personal priorities, which underpins the importance of the role of the instructor or educator in the learning experience. Most of the CFIs reported during the interviews that they did not see much room to address sustainability topics in practical teaching besides noise abatement, fuel-efficient flying techniques, and plane choice for training (e.g., light two-seater vs. heavy four-seater). However, there were substantial differences in their views.

While Interviewee 6 did not think sustainability is "(..) such a big issue at PPL level because there's a hobby behind it", Interviewee 5 saw an urgent need in increasing the extent that sustainability is taught in both theory and practical PPL(A) training, and remarked that the CFI and GA community needs to develop a common ethos and set of values regarding sustainability and SD. Interviewee 5 was the only CFI that reported to have critical discussions on sustainability with some students yet regretted that he usually addresses sustainability "[u]nfortunately too little and only on demand" in his practical training sessions while emphasizing that he is " (..) currently trying to define what our flight school is all about, what our values are and where we want to go in the future. One of the points is also that we focus more on sustainability awareness". He also advocated for an inclusion of sustainability topics in the practical national PPL(A) training syllabus as well as in the PPL(A) web-based training. Nevertheless, Interviewee 1 (CFI), argued "(..) compared to the rest of the world, it's already pretty good in Switzerland. (..) I wouldn't add a lot more on sustainability".

From these results, it becomes obvious that the main gap in addressing sustainability in PPL(A) learning material, theory and practical lessons can be considered the lack of a holistic sustainability perspective beyond fuel-efficiency and noise issues, as well as trigger to foster critical thinking and sustainability awareness in PPL(A) student pilots, e.g. adding discussions on mobility and climate injustice, (socioeconomic) privilege, and even gender-issues that have neither been addressed by any of the interviewees nor the learning materials. Especially, gender-equality and gender-related issues should be thematized as their importance in GA and PPL(A) training has been pointed out by Leuenberger and Lutte (2022).

Fostering awareness of sustainability issues is key to the success of ESD and transformative learning. The latter requires an initial disorienting dilemma which entails sustainability awareness. None of the interviewed student pilots reported that their views on sustainability or the sustainability impacts of GA had changed significantly with the exception of Interviewee 4 who argued that he learned about more sustainable aviation technologies, such as SAF and the option of electric flight training, during his PPL(A) training but did not "(..) have all that on [his] radar before".

Mezirow (1997, p. 7) explains in his theory that "thinking as an autonomous and responsible agent is essential for full citizenship in democracy and for moral decision making in situations of rapid change". This autonomous thinking which comes from emancipatory exploration and discovery of knowledge was not reflected in the learning experiences reported by the interviewed student pilots. For instance, Interviewee 3 stated "I just do it the way we learned and for the well-known reasons we were taught". Interviewee 4 argued he had discovered aviation and flying for himself to a limited extent but added "[t]he things are given and there are things that you just have to learn". While the student pilots did not experience a significant discovery process, the reported perspectives of the CFIs were contradicting this.

Interviewee 5 argued that his student pilots "(..) should discover flying. But I'm just wondering if that's the right way to go". Interviewee 1 also advocated for stimulating self-discovery during the learning process and reasoned that the student pilot "(..) has to discover it and realize". The role and potential impact of using a transformative learning approach suited the views of Interviewee 1 who tries "(..) to teach every pilot, no matter if it is just to do a PPL or LAPL, as if they will later be a commercial pilot". By applying a transformative approach to PPL(A) training, sustainability benefits beyond GA, e.g., when a private pilot decides to become a commercial or airline pilot which is quite a common sequence since the PPL(A) usually represents the first step in the pipeline to becoming a professional pilot (Leuenberger & Lutte, 2022).

The impacts of sustainability-minded aeronautical decision making of these former private pilots are much larger when they end up flying larger airplanes that burn more fuel and generate more noise. Also, other aspects, such as respecting women in aviation and supporting them to work towards a more gender-equal aviation industry should be kept in mind. The importance of this SD effort in relation to SDG 5 as addressed in Leuenberger and Lutte (2022) must not be overshadowed by an environmental and technological overfocus at the expense of the social dimension in the sustainable aviation discourse which is reflected in previous research, e.g. Edwards and Parker (2022); Stiebe (2022); Voipio (2022).

The empirical insights from this research point out major potentials for applying a transformative ESD approach to catalyze the sustainability transition in PPL(A) training and GA. Even though PPL(A) training underlies strict regulations and rigid, widely standardized educational structures, there is room to address sustainability issues and foster discovery learning, and critical thinking in flight students. According to Mezirow's transformative learning theory, the educator which, in the case of PPL(A) training, is a CFI and/or PPL(A) theory instructor should act as a *facilitator* and *provocateur* rather than an authority on the subject (Mezirow, 1997). This triggers the question of how this provocation and facilitation for a transformative ESD approach to PPL(A) training can be achieved

Since major differences between CFIs have been reported during the interviews, the role of the educator as a provocateur can only be achieved if the CFIs themselves undergo a continuing education including training and critical reflections on the sustainability impacts of aviation and their role as a facilitator of sustainable change rather than their traditional role as a CFI or theory instructor who just teaches a student how to operate an airplane. The role of the CFI must undergo a transformation so that he or she is capable of fostering critical reflection and discovery learning in students.

7.1. Methodological Discussion

This study was subject to many methodological limitations. The key limitations were a narrow geographical focus as well as a small interview sample. With regard to time availability and feasibility, the interview sample could have been increased by at least one more interviewee in each interviewee group. Furthermore, the chosen study could have benefited from an mixed-method approach by adding another method such as a quantitative survey, which would have helped to put the findings from the interviews into context and either support or reject certain statements. Participant observation in the field, i.e., theory lessons and practical training, over a longer period would have certainly added to the depth of the findings yet would not have been feasible considering the author's employment situation and limited time. Nevertheless, the document analysis proved to be a valuable tool to identify how sustainability and SD are taught to student pilots. This method could be adopted in a connecting study with a wider geographical focus. The number of subcodes should be reduced to avoid similar code overlaps as has occurred in this study.

8. Conclusions and Recommendations

This study investigated the special case of PPL(A) training through the lens of Education for Sustainable Development (ESD) and Mezirowian Transformative Learning Theory. The research made an important contribution to the field of education and ESD research as it was the first study to ever analyze PPL(A) training from these perspectives. This proves the flexibility and universal applicability of ESD and transformative learning outside the classical spectrum of formal education.

The methodological foundation of this thesis was a pragmatic multi-method approach. A thematic analysis of the most commonly used PPL(A) learning materials (Basic Aviation Knowledge BAK, and SPHAIR Grundlagen und Verfahren GuV) was complemented with a thematic analysis of interview data from six qualitative interviews with Swiss CFIs and flight students/recently certificated student pilots, three in each interviewee group. A hybrid coding approach was applied drawing on codes that were defined based on insights from the author's exploratory sustainability-focused GA study from 2022. The results from both analyses were triangulated and used to provide answers to the initial research questions which investigated 1) how sustainability and SD are taught in commonly used PPL(A) learning material, theory lessons, and practical PPL(A) flight training, 2) what gaps pertaining to teaching sustainability and SD exist in PPL(A) learning material, theory lessons, and practical PPL(A) training, and 3) how transformative learning is experiences by students and CFIs as well as how a transformative learning-based ESD approach to PPL(A) training could catalyze the sustainability transition in PPL(A) training and GA.

The document analysis revealed that sustainability and SD issues are only marginally taught in the most commonly used Swiss PPL(A) learning materials. This finding concurred with the reported perceptions of the interviewees, especially with those reported by the student pilots/recently certificated private pilots. The representation of those issues, particularly noise, noise abatement, and fuel-efficient flying techniques, proved to be very technical lacking critical discussion. While it showed that sustainability issues and SD do not see significant representation or thematization in PPL(A) theory lessons, both groups, CFIs and student pilots/recently certificated private pilots, reported that sustainability issues and SD were thematized to a comparably larger extent.

Overall, sustainability issues and SD have proven to be underrepresented and insufficiently thematized in PPL(A) learning material, theory lessons, as well as practical PPL(A) flight training, whereas sustainability issues are reportedly most prominent in practical flight training, particularly related to techniques that reduce noise, and fuel consumption, and thus correlatedly CO_2 emissions as well.

Learning materials and theory lessons are lacking critical sustainability discussions, a holistic sustainability discussion that addresses broader sustainability issues (e.g., gender-equality, mobility and climate justice etc.), and stimuli for students to reflect critically upon and develop sustainability awareness and the initial disorientating dilemma which is a necessary first step to experience transformative learning. The study showed that PPL(A) training in its current form is not transformative.

Based on the findings, which were discussed within the theoretical frame of Mezirowian transformative learning theory, the study concludes that a transformative ESD approach has the potential of catalyzing more sustainable PPL(A) training and GA. A necessary key condition for this are rigorous mutual sustainability efforts and a SD-oriented consensus in the GA and CFI community. To employ a transformative learning approach to PPL(A) training, the role of the CFI as a mere instructor needs to be reconsidered and reframed so that the *instructor* becomes an *educator*, and even more a *provocateur* and *facilitator* of transformative learning in flight students.

Drawing on the literature review and the primary research part of this study, potential ways to facilitate a transformative ESD learning experience in PPL(A) training were identified. The learning material for PPL(A) students should be revised in such a way that it incorporates facts and critical insights on the sustainability impacts (all three dimensions) of GA and flight training to raise awareness and provoke the important initial disorienting dilemma in student pilots, e.g., by presenting them right at the beginning of their training with key facts about the climate, health, noise and other sustainability impacts of GA. Raising sustainability awareness, triggering questions and even discussions between CFIs, theory instructors and students would favor inducing disorienting dilemmas.

Sustainability and SD should be incorporated in PPL(A) theory lessons and the theory syllabus in such a way that there is not just a transfer of knowledge but also room for reflection and critical discussions of the knowledge. Since theory lessons are often held as classroom sessions, occasional (small) group discussions, as suggested by Mezirow (1997), would be an asset to this learning format. Additionally, sustainability issues should be included to some extent in the theory examinations facilitated by civil aviation authorities, such as FOCA. Since the theoretical examinations in Switzerland are multiple-choice tests for each of the nine subjects, the possible inclusion of questions regarding such issues would be limited to hard facts which would have to relate to the content of the subject area (e.g., question on CO_2 contribution of GA in Switzerland, or percentage of Swiss inhabitants suffering from exposure to aviation noise emissions, etc.). Even though the critical reflection of the issues would not be possible in this exam format, the inclusion of sustainability-related questions on the test would guarantee that the students to be examined at least reflect a bit on these issues during their preparatory study period.

Even though safety must remain the primary objective of practical flight training, sustainability should gain more importance. However, critical discussions about gender-inequality or poverty, for instance, should not be held during a training flight since it may distract the student and CFI and pose safety risks. Nevertheless, environmentally-, and socially-minded behaviors could become a subject to discuss in the cockpit and conduct in practice. An orientation example for this could be the inclusion of *Eco-Driving*[13] as a mandatory component of car driver tests in all countries of the European Union since 2013 (Huang et al., 2018). Could such a mandatory *Eco-Flying* emphasis be implemented into PPL(A) training? Considering the average GA aircraft fleet age, especially trainer planes, where the pilot still has substantial influence on the fuel economy (fuel mixing and "leaning") and CO_2 emissions, such an initiative would be advisable. Making it a mandatory component of the checkride would could increase awareness about their flying techniques in relation to sustainability, especially environmental issues.

Since the private pilot license is often the first step in the career of later commercial and airline pilots, a transformative ESD approach to PPL(A) training has the potential of not just catalyzing the sustainability transition in GA but also commercial aviation. Finally, in an age of ever more dire sustainability crises on our planet, becoming a pilot simply cannot be just about learning how to operate an airplane anymore. GA has long flown under the radar of sustainability. This will not be the case anymore in the near future. To preserve the privilege of flying as a private pilot, the GA community needs to become self-aware, self-critical, sustainability-minded, and an agent of change for SD.

8.1. Future Research

Future research could explore the role of sustainability education in training CFIs and the role of flight training organizations in facilitating sustainability transition in GA. The author suggests expanding the geographical scope of research to include various cultural contexts, such as EASA member states, the United States, and Australia, to identify SD potentials and promote transnational collaboration (cf. SDG17). Additionally, future research could examine the extent to which sustainability topics are addressed in various PPL(A) learning materials, including textbooks and applications, to evaluate differences and commonalities.

[13] Eco-driving is a mindful driving technique that aims to reduce fuel consumption, carbon emissions, and environmental impact by adjusting driving behaviors such as smooth acceleration, maintaining a steady speed, and reducing idling time., see e.g., https://tti.tamu.edu/researcher/eco-driving-means-driving-smarter/

References

Afonso, F., Sohst, M., Diogo, C. M., Rodrigues, S. S., Ferreira, A., Ribeiro, I., Marques, R., Rego, F. F., Sohouli, A., & Portugal-Pereira, J. (2023). Strategies towards a more sustainable aviation: A systematic review. *Progress in Aerospace Sciences*, *137*, 100878.

All European Academies. (2017). *The European code of conduct for research integrity*. European Science Foundation. https://www.allea.org/wp-content/uploads/2017/05/ALLEA-European-Code-of-Conduct-for-Research-Integrity-2017.pdf

Alluisi, S. J. (1997). *A survey of Certified Flight Instructors: Self-reported assessments of depth and breadth of knowledge and confidence to teach private pilot students*. Oklahoma State University.

Angrand, R. C., Collins, G., Landrigan, P. J., & Thomas, V. M. (2022). Health Effects of Removing Lead from Gasoline: A Systematic Review.

Antuñano, M. J., & Spanyers, J. P. (2006). *Hearing and noise in aviation*.

AOPA. (2008). *REGULATORY BRIEF - GENERAL AVIATION AND GREENHOUSE GAS EMISSION*. Aircraft Owners and Pilots Association. Retrieved April 14 from https://www.aopa.org/advocacy/advocacy-briefs/regulatory-brief-general-aviation-and-greenhouse-gas-emission

Atalay, H., Babakurban, S. T., & Aydın, E. (2015). Evaluation of hearing loss in pilots. *Turkish Archives of Otorhinolaryngology*, *53*(4), 155.

Bali Swain, R., & Yang-Wallentin, F. (2020). Achieving sustainable development goals: predicaments and strategies. *International Journal of Sustainable Development & World Ecology*, *27*(2), 96-106.

Banerjee, A. (2012). Sustainable Development—Issues and Critics from Indian Perspective. *Management Accountant-New Delhi*, *47*(3), 286.

Barkemeyer, R., Holt, D., Preuss, L., & Tsang, S. (2014). What happened to the 'development'in sustainable development? Business guidelines two decades after Brundtland. *Sustainable development*, *22*(1), 15-32.

Bazargan, M., & Guzhva, V. S. (2011). Impact of gender, age and experience of pilots on general aviation accidents. *Accident Analysis & Prevention*, *43*(3), 962-970.

Beringer, D. B., & Harris Jr, H. C. (2005). *A comparison of baseline hearing thresholds between pilots and non-pilots and the effects of engine noise*.

Berton, J. J., & Nark, D. M. (2019). Low-noise operating mode for propeller-driven electric airplanes. *Journal of Aircraft*, *56*(4), 1708-1714.

Boeve-de Pauw, J., Gericke, N., Olsson, D., & Berglund, T. (2015). The effectiveness of education for sustainable development. *Sustainability*, *7*(11), 15693-15717.

Boström, M., Andersson, E., Berg, M., Gustafsson, K., Gustavsson, E., Hysing, E., Lidskog, R., Löfmarck, E., Ojala, M., & Olsson, J. (2018). Conditions for transformative learning for sustainable development: A theoretical review and approach. *Sustainability*, *10*(12), 4479.

Boyer, R. H., Peterson, N. D., Arora, P., & Caldwell, K. (2016). Five approaches to social sustainability and an integrated way forward. *Sustainability*, *8*(9), 878.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*, *3*(2), 77-101.

Buckler, C., & Creech, H. (2014). *Shaping the future we want: UN Decade of Education for Sustainable Development; final report*. Unesco.

Bylund, L., Hellberg, S., & Knutsson, B. (2022). 'We must urgently learn to live differently': the biopolitics of ESD for 2030. *Environmental Education Research*, *28*(1), 40-55.

Cloche, M. (2010). Hot topics in general aviation: sustainable aviation gasoline alternatives. *International School of Management in Paris, France*.

Cohen, S., Liu, H., Hanna, P., Hopkins, D., Higham, J., & Gössling, S. (2022). The rich kids of Instagram: Luxury travel, transport modes, and desire. *Journal of Travel Research*, *61*(7), 1479-1494.

Continental Aerospace Technologies. (2022). *Diesel Engines*. Continental Aerospace Technologies GmbH, D-09356 St. Egidien. Retrieved May 14 from http://www.continentaldiesel.com/typo3/index.php?id=59&L=1.

Dib, C. Z. (1988). Formal, non-formal and informal education: concepts/applicability. AIP conference proceedings,

Dimitriou, D. J., & Sartzetaki, M. F. (2020). Social dimensions of aviation on sustainable development. *Sustainable Aviation: Greening the Flight Path*, 173-191.

Dimitrov, D. (2010). The paradox of sustainability definitions. Sixth Asia pacific Interdisciplinary Research in Accounting Conference,

Dymitrow, M., & Halfacree, K. (2018). Sustainability—differently. *Bulletin of Geography. Socio-economic Series*(40), 7-16.

EASA. (2022). *Sustainable Pilot Training Webinar*. EASA. Retrieved December 12 from https://www.easa.europa.eu/en/newsroom-and-events/events/sustainable-pilot-training-webinar

Edwards, C., & Parker, P. (2022). Flight School Perceptions of Electric Planes for Training. *International Journal of Aerospace and Mechanical Engineering*, *16*(1), 11-19.

Elkington, J. (1997). The triple bottom line. *Environmental management: Readings and cases*, *2*, 49-66.

Ennels, J. A. (2002). The" Wright stuff" pilot training at America's first civilian flying school. *Air Power History*, *49*(4), 22-31.

Commission Regulation (EU) No 1178/2011 of 3 November 2011 laying down technical requirements and administrative procedures related to civil aviation aircrew pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council Text with EEA relevance, (2022). https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32011R1178

FAA. (2014). *White Paper - Piston Aviation Fuel Initiative*. Online: Federal Aviation Administration Retrieved from faa.gov/sites/faa.gov/files/about/initiatives/avgas/org_info/PAFI_White_Paper.pdf

FAA. (2019, November 20, 2019). *Leaded Aviation Fuel and the Environment*. Federal Aviation Administation. Retrieved March 4 from https://www.faa.gov/newsroom/leaded-aviation-fuel-and-environment

FAA. (2021). *United States 2021 Aviation Climate Action Plan*. Federal Aviation Administration. https://www.faa.gov/sites/faa.gov/files/2021-11/Aviation_Climate_Action_Plan.pdf

FAA. (2022). *FAA, Industry Chart Path to Eliminate Lead Emissions from General Aviation by the end of 2030*. Federal Aviation Administration. Retrieved April 15 from https://www.faa.gov/newsroom/faa-industry-chart-path-eliminate-lead-emissions-general-aviation-end-2030

Federal Statistical Office. (2022). Schweizerische Zivilluftfahrt. In su-b-438-11.7.AV-e-3.xlsx (Ed.). Federal Statistical Office: Federal Statistical Office.

FlyGA. (2022). *What's the Difference Between the EASA PPL & LAPL?* FlyGA,. Retrieved May 12 from https://fly-ga.co.uk/difference-between-easa-ppl-lapl/

FOCA. (2007). *Schadstoffemissionen von Flugzeugkolbenmotoren: Zusammenfassender Bericht*. https://www.bazl.admin.ch/dam/bazl/de/dokumente/Fachleute/Regulationen_und_Grundlagen/kolbenmotoremissionenberichtinklalleanhaenge.pdf.download.pdf/kolbenmotoremissionenberichtinklalleanhaenge.pdf

FOCA. (2022a). *Noise-related landing charges*. Federal Office of Civil Aviation. Retrieved May 7 from https://www.bazl.admin.ch/bazl/en/home/specialists/aircraft/noise-related-landing-charges.html

FOCA. (2022b). *Reducing aircraft noise*. Federal Office of Civil Aviation. Retrieved May 7 from https://www.bazl.admin.ch/bazl/en/home/specialists/regulations-and-guidelines/environment/reducing-aircraft-noise.html

FOCA. (2022c). *Swiss civil aviation 2021*. Federal Statistical Office. Retrieved April 10 from https://dam-api.bfs.admin.ch/hub/api/dam/assets/23265985/master

FOCA. (2023). *Key figures on civil aviation in 2021*. Federal Statistical Office. Retrieved April 15 from https://www.bfs.admin.ch/bfs/en/home/statistics/mobility-transport/cross-sectional-topics/civil-aviation.html

Francis, J. J., Johnston, M., Robertson, C., Glidewell, L., Entwistle, V., Eccles, M. P., & Grimshaw, J. M. (2010). What is an adequate sample size? Operationalising data saturation for theory-based interview studies. *Psychology and health*, *25*(10), 1229-1245.

Franz, K., Risse, K., & Stumpf, E. (2013). Framework for sustainability-driven aircraft design. 2013 Aviation Technology, Integration, and Operations Conference,

GAVI. (2022). *Millennium Development Goals*. GAVI. Retrieved April 2 from https://www.gavi.org/our-alliance/global-health-development/millennium-development-goals

Germain, M.-L., Herzog, M. J. R., & Hamilton, P. R. (2012). Women employed in male-dominated industries: Lessons learned from female aircraft pilots, pilots-in-training and mixed-gender flight instructors. *Human Resource Development International*, *15*(4), 435-453.

Glavič, P. (2020). Identifying key issues of education for sustainable development. *Sustainability*, *12*(16), 6500.

Gössling, S., & Humpe, A. (2020). The global scale, distribution and growth of aviation: Implications for climate change. *Global Environmental Change*, *65*, 102194.

Graver, B., Zhang, K., & Rutherford, D. (2019). emissions from commercial aviation, 2018. In: The International Council on Clean Transportation.

Guest, G., Bunce, A., & Johnson, L. (2006). How many interviews are enough? An experiment with data saturation and variability. *Field methods*, *18*(1), 59-82.

Haygood, J. (2021, October 28, 2021). *How Many Pilots Are There? (USA, Air Force, World)*. Skytough. Retrieved April 14 from https://www.skytough.com/post/how-many-pilots-are-there

Hjelmco Oil AB. (2022). *Noise*. Hjelmco Oil AB. Retrieved April 26 from https://www.hjelmco.com/pages.asp?r_id=14009

Homola, D., Boril, J., Smrz, V., Leuchter, J., & Blasch, E. (2019). Aviation noise-pollution mitigation through redesign of aircraft departures. *Journal of Aircraft*, *56*(5), 1907-1919.

Hopkins, C., & McKeown, R. (2002). Education for sustainable development: an international perspective. *Education and sustainability: Responding to the global challenge*, *13*, 13-24.

Huang, Y., Ng, E. C., Zhou, J. L., Surawski, N. C., Chan, E. F., & Hong, G. (2018). Eco-driving technology for sustainable road transport: A review. *Renewable and Sustainable Energy Reviews*, *93*, 596-609.

Hwang, H.-J., & Choi, J.-K. (2022). A Thought on the Flight Training of the Students in Department of Flight Operation under COVID-19. *항공우주의학회지*, *32*(2), 60-64.

IAOPA Europe. (2022). *What is General Aviation*. The International Council of Aircraft Owner and Pilot Associations (IAOPA). Retrieved May 7 from https://www.iaopa.eu/what-is-general-aviation

IAOPA Europe. (2023). *What is General Aviation*. The International Council of Aircraft Owner and Pilot Associations (IAOPA). Retrieved Feburary 13 from https://www.iaopa.eu/what-is-general-aviation

Ideland, M., & Malmberg, C. (2015). Governing 'eco-certified children'through pastoral power: critical perspectives on education for sustainable development. *Environmental Education Research*, *21*(2), 173-182.

Imber, M. F. (1993). The United Nations' role in sustainable development. *Environmental Politics*, *2*(4), 123-136.

Jäger, E. (1950). Flugverkehr und Tourismus. *The Tourist Review*, *5*(3), 108-121.

Jin, L., Cao, Y., & Sun, D. (2013). Investigation of potential fuel savings due to continuous-descent approach. *Journal of Aircraft*, *50*(3), 807-816.

Joubert, E., Chapuis, D., Esteyne, D., Lambert, J.-C., Siri, O., & Müller-Wiesner, D. (2016). The E-Fan all electrical aircraft demonstrator and its industrialization. Proceedings of the 30th Congress of the International Council of the Aeronautical Sciences,

Kahn, R. V. (2010). *Critical pedagogy, ecoliteracy, & planetary crisis: The ecopedagogy movement* (Vol. 359). Peter Lang.

Kaushik, V., & Walsh, C. A. (2019). Pragmatism as a research paradigm and its implications for social work research. *Social sciences*, *8*(9), 255.

Kitchenham, A. (2008). The evolution of John Mezirow's transformative learning theory. *Journal of transformative education*, *6*(2), 104-123.

Kitchenham, A. (2012). Jack Mezirow on transformative learning. *Encyclopedia of the sciences of learning*, 1659-1661.

Kopnina, H. (2012). Education for sustainable development (ESD): The turn away from 'environment'in environmental education? *Environmental Education Research*, *18*(5), 699-717.

Kopnina, H. (2014). Revisiting education for sustainable development (ESD): Examining anthropocentric bias through the transition of environmental education to ESD. *Sustainable development*, *22*(2), 73-83.

Kopnina, H., Washington, H., Taylor, B., & J Piccolo, J. (2018). Anthropocentrism: More than just a misunderstood problem. *Journal of Agricultural and Environmental Ethics*, *31*(1), 109-127.

Kreis, G. (2016). *Die Schweiz im Zweiten Weltkrieg*. Haymon Verlag.

Kumar, T. (2019). *PARAMETRIC PERFORMANCE AND OPERATIONAL CHARACTERISTICS OF MOTOR GASOLINE FUEL USING LYCOMING O-320 AVIATION ENGINE* Universiti Teknologi Malaysia].

Kumar, T., Mohsin, R., Ghafir, M. F. A., Kumar, I., & Wash, A. M. (2018). Concerns over use of leaded aviation gasoline (AVGAS) fuel. *Chemical Engineering Transactions*, *63*, 181-186.

Kumar, T., Mohsin, R., Majid, Z. A., Ghafir, M. F. A., & Wash, A. M. (2020). Experimental optimisation comparison of detonation characteristics between leaded aviation gasoline low lead and its possible unleaded alternatives. *Fuel*, *281*, 118726.

Leipzig University. (n.d.). *Samplingstrategien*. Leipzig University. Retrieved March 15 from https://home.uni-leipzig.de/methodenportal/samplingstrategien/

Leuenberger, D. Z., & Lutte, R. (2022). Sustainability, Gender Equity, and Air Transport: Planning a Stronger Future. *Public Works Management & Policy*, *27*(3), 238-251.

Levin, R., Vieira, C. L. Z., Rosenbaum, M. H., Bischoff, K., Mordarski, D. C., & Brown, M. J. (2021). The urban lead (Pb) burden in humans, animals and the natural environment. *Environmental research*, *193*, 110377.

Luebbers, T. (2019). Aging pilots, aging airplanes. *General Aviation News*. https://generalaviationnews.com/2019/05/27/aging-pilots-aging-airplanes/

Lukasch, B. (2003). From Lilienthal to the Wrights. *Otto-Lilienthal-Museum Anklam*.

Manolescu, I.-T., Florea, N., & Arustei, C.-C. (2018). Forms of learning within higher education. blending formal, informal and non-formal. *Cross-Cultural Management Journal*, *20*(1), 7.

Marsh, W. L. (1926). Arctic Exploration by Air. *The English review*, *1908-1937*, 270-273.

Maxcy, S. J. (2003). Pragmatic threads in mixed methods research in the social sciences: The search for multiple modes of inquiry and the end of the philosophy of formalism. *Handbook of mixed methods in social and behavioral research*(51-89).

McArthur, J. W. (2014). The origins of the millennium development goals. *The SAIS Review of International Affairs*, *34*(2), 5-24.

Mendonca, F. A. C., & Keller, J. (2022). Enhancing the Aeronautical Decision-Making Knowledge and Skills of General Aviation Pilots to Mitigate the Risk of Bird Strikes: A Quasi-Experimental Study. *The Collegiate Aviation Review International*, *40*(2).

Meyer, J. D. (2021). Examining Crucial Demographic Trends in General Aviation. https://scholar.afit.edu/cgi/viewcontent.cgi?article=5935&context=etd

Mezirow, J. (1997). Transformative learning: Theory to practice. *New directions for adult and continuing education*, *1997*(74), 5-12.

Mezirow, J. (2008). An overview on transformative learning. *Lifelong learning*, 40-54.

Min, S., Lim, D., & Mavris, D. N. (2015). Aircraft Noise Reduction Technology and Airport Noise Analysis for General Aviation Revitalization. 15th AIAA Aviation Technology, Integration, and Operations Conference,

Mitchell, J., Kristovics, A., Vermeulen, L., Wilson, J., & Martinussen, M. (2005). How pink is the sky?: a cross-national study of the gendered occupation of pilot. *Employment Relations Record*, *5*(2), 43-60.

Murphy, R. (2012). Sustainability: A wicked problem. *Sociologica*, *6*(2), 0-0.

myclimate. (2023). *What are the Sustainable Development Goals (SDGs)?* myclimate.org. Retrieved April 2 from https://www.myclimate.org/information/faq/faq-detail/what-are-the-sustainable-development-goals-sdgs/

NASA. (2022). *Sustainable Aviation*. NASA. Retrieved January 31 from https://www.nasa.gov/aeroresearch/programs/iasp/sa/description/

Nie, V., Devey, P., & Brown, A. (1997). Noise exposures and risks of hearing loss in pilots of general aviation aircraft. *Occupational Health and Industrial Medicine*, *2*(37), 70.

Olawuyi, D. S. (2016). Sustainable aviation and the transfer of environmentally sound technologies to Africa: Paradoxes, barriers and prospects. *Occasional paper No. XIII. McGrill University. Quebec University. https://www. mcgill. ca/iasl/files/iasl/xiii_sustainable_aviation_and_the_transfer_of_environmentally_sound_technologies_final. pdf.*

Orb, A., Eisenhauer, L., & Wynaden, D. (2001). Ethics in qualitative research. *Journal of nursing scholarship*, *33*(1), 93-96.

Orlović Lovren, V., & Popović, K. (2018). Lifelong Learning for Sustainable Development—Is Adult Education Left Behind? In *Handbook of lifelong learning for sustainable development* (pp. 1-17). Springer.

Ormerod, R. (2006). The history and ideas of pragmatism. *Journal of the Operational Research Society*, *57*, 892-909.

Pandey, N., & Vedak, V. (2010). Structural transformation of education for sustainable development. *International journal of environment and sustainable development*, *9*(1-3), 3-15.

Parks, D. (2015). *Flight training the Wright way*. Flyer Media, Inc. Retrieved April 10 from https://generalaviationnews.com/2015/03/08/flight-training-the-wright-way/

Parris, T. M., & Kates, R. W. (2003). Characterizing and measuring sustainable development. *Annual Review of environment and resources*, *28*(1), 559-586.

Parvaiz, G. S., Mufti, O., & Wahab, M. (2016). Pragmatism for mixed method research at higher education level. *Business & Economic Review*, *8*(2), 67-79.

Penner, J., Lister, D., Griggs, D., Dokken, D., & MCFAR-LAND, M. (1999). Aviation and the global atmosphere: Summary for policymakers, IPCC Special Report. In: Cambridge University Press, Cambridge, UK.

Pilot Institute. (2021). *How High Do Planes Fly? Airplane Flight Altitude*. Pilot Institute. Retrieved April 14 from https://pilotinstitute.com/airplane-height/

Proudfoot, K. (2022). Inductive/Deductive hybrid thematic analysis in mixed methods research. *Journal of Mixed Methods Research*, 15586898221126816.

Purvis, B., Mao, Y., & Robinson, D. (2019). Three pillars of sustainability: in search of conceptual origins. *Sustainability science*, *14*, 681-695.

Rao, V. C. S. (2018). The use of English language in research. *Journal for Research Scholars and Professionals of English Language Teaching*, *2*(8), 124-135.

Reigel, G. (2013). *Flying Is A Privilege, Not A Right*. Shackelford, Bowen, McKinley & Norton, LLP. Retrieved April 10 from https://shackelford.law/news-aviation/flying-is-a-privilege-not-a-right/

Riboldi, C. E., Trainelli, L., Mariani, L., Rolando, A., & Salucci, F. (2020). Predicting the effect of electric and hybrid-electric aviation on acoustic pollution. *Noise Mapping*, *7*(1), 35-56.

Rodríguez Aboytes, J. G., & Barth, M. (2020). Transformative learning in the field of sustainability: a systematic literature review (1999-2019). *International Journal of Sustainability in Higher Education*, *21*(5), 993-1013.

Rowlands, T., Waddell, N., & McKenna, B. (2016). Are we there yet? A technique to determine theoretical saturation. *Journal of Computer Information Systems*, *56*(1), 40-47.

Saunders, B., Sim, J., Kingstone, T., Baker, S., Waterfield, J., Bartlam, B., Burroughs, H., & Jinks, C. (2018). Saturation in qualitative research: exploring its conceptualization and operationalization. *Quality & quantity*, *52*, 1893-1907.

Schaffernak, H., Moesl, B., Vorraber, W., Holy, M., Herzog, E.-M., Novak, R., & Koglbauer, I. V. (2022). Novel Mixed Reality Use Cases for Pilot Training. *Education Sciences*, *12*(5), 345.

Schaffernak, H., Moesl, B., Vorraber, W., & Koglbauer, I. V. (2020). Potential augmented reality application areas for pilot education: An exploratory study. *Education Sciences*, *10*(4), 86.

Scheelhaase, J., Dahlmann, K., Jung, M., Keimel, H., Murphy, M., Nieße, H., Sausen, R., Schaefer, M., & Wolters, F. (2015). Die Einbeziehung des Luftverkehrs in internationale Klimaschutzprotokolle (AviClim)-Abschlussbericht.

Schlittler, T. (2018). Weniger Piloten, weniger Flugzeuge. Die Flaute in der Schweizer Fliegerei. *Blick*. https://www.blick.ch/news/weniger-piloten-weniger-flugzeuge-die-flaute-in-der-schweizer-fliegerei-id8743382.html

Seghezzo, L. (2009). The five dimensions of sustainability. *Environmental Politics*, *18*(4), 539-556.

Simsek, A. (2012). Transformational learning. *Encyclopedia of the sciences of learning*, 3341-3343.

SKYbrary. (2023). *General Aviation*. SKYbrary Aviation Safety. Retrieved February 13 from https://www.skybrary.aero/articles/general-aviation-ga

Sobieralski, J. B., & Mumbower, S. (2022). Jet-setting during COVID-19: Environmental implications of the pandemic induced private aviation boom. *Transportation Research Interdisciplinary Perspectives*, 100575.

Sobotta, R. R., Campbell, H. E., & Owens, B. J. (2007). Aviation noise and environmental justice: The barrio barrier. *Journal of Regional Science*, *47*(1), 125-154.

Stiebe, M. (2022). *Come Fly with Me (Sustainably): Pathways to Sustainable General Aviation and Private Pilot Training* [Master's Thesis, University of Gävle]. http://urn.kb.se/resolve?urn=urn:nbn:se:hig:diva-39366

Tagesanzeiger. (2010). Flugpionier Alfred Comte. *Tagesanzeiger*. https://www.tagesanzeiger.ch/flugpionier-alfred-comte-149330275948

Taylor, A., Dixon-Hardy, D. W., & Wright, S. J. (2014). Simulation training in UK general aviation: An undervalued aid to reducing loss of control accidents. *The International Journal of Aviation Psychology*, *24*(2), 141-152.

Turnbull, A. (1999). *The typical general aviation aircraft*.

Twinn, S. (1997). An exploratory study examining the influence of translation on the validity and reliability of qualitative data in nursing research. *Journal of advanced nursing*, *26*(2), 418-423.

University of Michigan. (2023). *Sustainable Aviation*. College of Engineering, Aerospace Engineering, University of Michigan. Retrieved January 31 from https://aero.engin.umich.edu/research/research-areas/sustainable-aviation/

Vermeulen, L. P. (2009). Flight instructors' perceptions of pilot behaviour related to gender. *SA Journal of Industrial Psychology*, *35*(1), 1-8.

Vetenskapsrådet. (2017). *GOOD RESEARCH PRACTICE*. Vetenskapsrådet. https://www.vr.se/download/18.5639980c162791bbfe697882/1555334908942/Good-Research-Practice_VR_2017.pdf

Voipio, L. (2022). eVTOLs and Pilot Training–The Impact of Electric Vertical Takeoff and Landing Aircrafts to Pilot Training.

Walker, S., & Cook, M. (2009). The contested concept of sustainable aviation. *Sustainable Development*, *17*(6), 378-390.

Wals, A. E., & Kieft, G. (2010). Education for sustainable development: Research overview.

Waseem, N., & Kota, S. (2017). Sustainability definitions—An analysis. Research into Design for Communities, Volume 2: Proceedings of ICoRD 2017,

WCED. (1987). Our common future—The Brundtland report. *Report of the World Commission on Environment and Development*.

Zahran, S., Iverson, T., McElmurry, S. P., & Weiler, S. (2017). The effect of leaded aviation gasoline on blood lead in children. *Journal of the Association of Environmental and Resource Economists*, *4*(2), 575-610.

Zero Petroleum. (2021, November 17, 2021). *Zero Petroleum and the Royal Air Force Announce the Completion of the World's First Flight using 100% Net-Zero Synthetic Fuel within the Framework of their Recent Partnership* https://zeropetroleum.com/wp-content/uploads/2021/11/Zero-Petroleum-and-RAF-First-100-Synthetic-Fuel-Flight..pdf

ZIPPIA. (2022). *PRIVATE PILOT DEMOGRAPHICS AND STATISTICS IN THE US*. ZIPPIA, INC. Retrieved April 15 from https://www.zippia.com/private-pilot-jobs/demographics/

Appendices

Appendix 1: Typological Overview of General Aviation (GA)

Typological Overview of Aviation Sectors and Associated Activities, based on IAOPA Europe (2023) (General Aviation = Yellow)

AVIATION

CIVIL AVIATION			STATE AIRCRAFT
GENERAL AVIATION (GA)		**COMMERCIAL AIR TRANSPORT (CAT)**	
• **Corporate Aviation** Company own-use flight operations • **Fractional Ownership Operations** aircraft operated by a specialized company on behalf of two or more co-owners • **Business Aviation (or Travel)** self-flown for business purposes • **Personal/ Private Travel** travel for personal reasons/ personal transport • **Air Tourism** self-flown incoming/ outgoing tourism • **Recreational Flying** powered/ powerless leisure flying activities • **Air Sports** Aerobatics, Air Races, Competitions, Rallies etc.	• **Aerial Crane Operations** • **Aerial Survey and Charting** • **Agricultural Flights (Crop Dusting) Aircraft Sales** • **Banner Towing/ Advertising Flights** • **Environment Surveillance and Enforcement** • **Ferry Flights/ Delivery Flights** • **Flight Demonstra-tions (Air Shows)** • **Fire Fighting (Forest Fires etc.)** • **Glider Towing** • **Medical Evacuations** • **Nostalgy Flights in Historic Aircraft** • **Pilot Training (from private to airline pilots)** • **Research and Development Flights** • **Search and Rescue** • **Sight Seeing Flights** • **Skydiver Hoisting** • **Supplies Dropping** • **Test Flights** • **Traffic Surveillance** • **Transplant Organ Transports** • **TV-Live Reporting** • **Weather Research**	***includes*** • **Scheduled Air Services** • **Non-Scheduled Air Transport** • **Air Cargo Services** • **Air Taxi Operations** (see note) The criteria to determine "commercial" or "non-commercial" (general aviation) is the fact of **paying for the purpose of transportation** from A to B, not of paying or not, nor of being flown by paid (employed) crew. NOTE: Aircraft types used and the operational similarity of Air Taxi are much closer to General Aviation than to Commercial Air Transport. Therefore, albeit not being GA&AW according to ICAO definitions, in some countries it is considered part of GA&AW and thus represented by the national AOPA).	***includes*** • **State VIP Transports** • **Police/ Customs Aircraft** • **General Air Traffic (MIL)** (not to be confused with General Aviation) Transport, Civil Support or Ferry missions where airspace and ATC of mainly civil air traffic is used. • **Operational Air Traffic (MIL)** Operations within the States' defined Missions of the Air Force, including surveillance/ identification, air superiority defence, tactical intelligence/ photography, ground troops support, etc., including training for such operations. NOTE: State aircraft (VIP, Police etc.) may be General Aviation/Aerial Work if aircraft are on the civil register but may benefit from State Aircraft status.

Appendix 2: Literature Review Process

PHASE 1 – SEARCH QUERY DEFINITION

The English search queries were:

- "SUSTAINABLE" AND "PRIVATE PILOT TRAINING"
- "SUSTAINABLE" AND "PRIVATE PILOTS"
- "SUSTAINABILITY" AND "PRIVATE PILOT TRAINING"
- "SUSTAINABILITY" AND "PRIVATE PILOTS"

The German search queries were:

- "NACHHALTIG" AND "PRIVATPILOTENAUSBILDUNG"
- "NACHHALTIG" AND "PRIVATPILOTEN"
- "NACHHALTIGKEIT" AND "PRIVATPILOTENAUSBILDUNG"
- "NACHHALTIGKEIT" AND "PRIVATPILOTEN"

PHASE 2 – SEARCH PHASE

The first search phase showed that most search results were yielded using Google Scholar, followed by JSTOR. Scopus and Web of Science did not yield any significant search results. An overview of the search results can be seen in Table 8 and *Figure 27*.

Table 8: Literature Search Results based on Eight Search Queries in English and German on Four Databases

LANGUAGE	SEARCH QUERY	GOOGLE SCHOLAR	SCOPUS	WEB OF SCIENCE	JSTOR
ENGLISH	"SUSTAINABLE" AND "PRIVATE PILOT TRAINING"	12	0	0	1
	"SUSTAINABLE" AND "PRIVATE PILOTS"	247	0	0	12
	"SUSTAINABILITY" AND "PRIVATE PILOT TRAINING"	17	0	0	1
	"SUSTAINABILITY" AND "PRIVATE PILOTS"	220	1	0	13
GERMAN	"NACHHALTIG" AND "PRIVATPILOTENAUSBILDUNG"	1	0	0	0

“NACHHALTIG” AND “PRIVATPILOTEN”	26	0	0	0
“NACHHALTIGKEIT” AND “PRIVATPILOTENAUSBILDUNG”	0	0	0	0
“NACHHALTIGKEIT” AND “PRIVATPILOTEN”	8	0	0	0

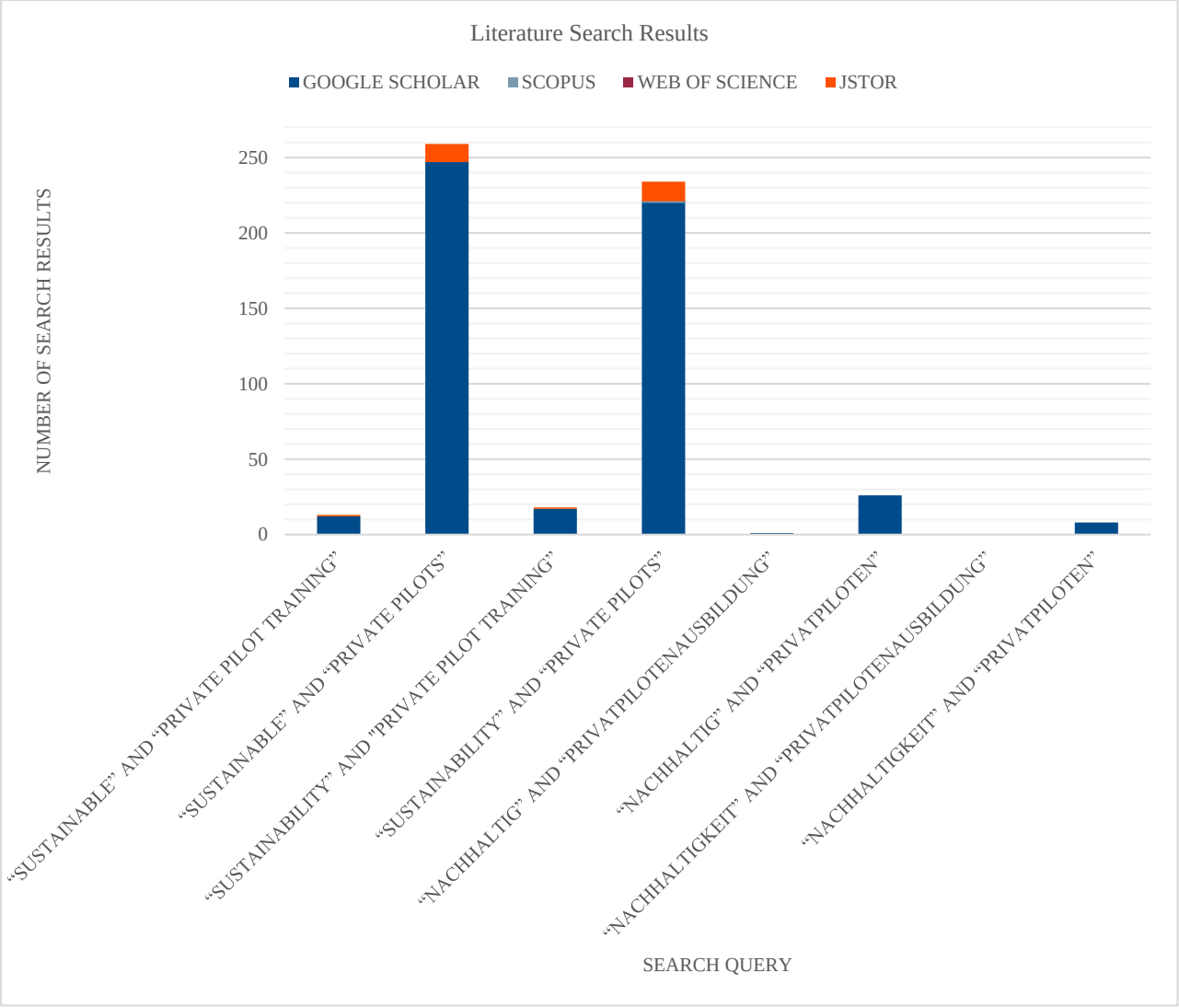


Figure 27: Overview of Literature Search Results

PHASE 3 – FILTERING RESULTS

Since some of the articles suggested by the search results were not topically related to the thesis' research focus, some results had to be excluded through a filtering process based on certain criteria.

The filtering process entailed three exclusion stages, namely 1) exclusion by title, and 2) exclusion by abstract, and 3) exclusion after full review. This means that if the investigated research topic was not reflected in or at least implied by the title of the study so that there could have been a chance the article addresses the thesis research focus to some extent, the study would be excluded from the review. In a second step, the remaining articles' abstracts were read to check whether the study related to the thesis research focus. If a thematic relation to the thesis research focus was not evident, the article was excluded. In a third and last step, a full review of the remaining articles was conducted to see whether the research focus was reflected to any relevant degree. If an article successfully passed all three stages, it was included in the thesis literature review preselection. This was the case for 17 articles out of which eventually seven duplicate entries were removed. This filtering process for which an overview is provided in *Table 9* yielded a total of ten academic publications that were deemed to be pertinent to the research focus and questions. The list of these remaining papers can be seen in *Table 10*.

Search Query Legend for Table 9:

I. "SUSTAINABLE" AND "PRIVATE PILOT TRAINING"
II. "SUSTAINABLE" AND "PRIVATE PILOTS"
III. "SUSTAINABILITY" AND "PRIVATE PILOT TRAINING"
IV. "SUSTAINABILITY" AND "PRIVATE PILOTS"
V. "NACHHALTIG" AND "PRIVATPILOTENAUSBILDUNG"
VI. "NACHHALTIG" AND "PRIVATPILOTEN"
VII. "NACHHALTIGKEIT" AND "PRIVATPILOTENAUSBILDUNG"
VIII. "NACHHALTIGKEIT" AND "PRIVATPILOTEN"

Table 9: Literature Filtering Results before Duplicate Removal

Platform	Lang	Query	Results	Exclusion by Title	Exlusion by Abstract	Exclusion after Full Review	Remaining Sample
	EN	I	12	3	6	1	2

GOOGLE SCHOLAR		II	247	229	9	1	8
		III	17	13	2	0	2
		IV	220	212	3	0	5
	GER	V	1	0	0	1	0
		VI	26	24	1	1	0
		VII	0	0	0	0	0
		VIII	8	6	1	1	0
SCOPUS	**EN**	I	0	0	0	0	0
		II	0	0	0	0	0
		III	0	0	0	0	0
		IV	1	1	0	0	0
	GER	V	0	0	0	0	0
		VI	0	0	0	0	0
		VII	0	0	0	0	0
		VIII	0	0	0	0	0
WEB OF SCIENCE	**EN**	I	0	0	0	0	0
		II	0	0	0	0	0
		III	0	0	0	0	0
		IV	0	0	0	0	0
	GER	V	0	0	0	0	0
		VI	0	0	0	0	0
		VII	0	0	0	0	0
		VIII	0	0	0	0	0
JSTOR	**EN**	I	1	1	0	0	0

		II	12	11	1	0	0
		III	1	1	0	0	0
		IV	13	13	0	0	0
	GER	V	0	0	0	0	0
		VI	0	0	0	0	0
		VII	0	0	0	0	0
		VIII	0	0	0	0	0
TOTAL			**559**	**514**	**23**	**5**	**17**

Table 10: Selected Articles after Duplicate Removal, Descending Chronological Order

YEAR	AUTHOR(S)	TITLE	TYPE	DOI / LINK
2022	Cohen, S., Liu, H., Hanna, P., Hopkins, D., Higham, J., & Gössling, S.	The rich kids of Instagram: Luxury travel, transport modes, and desire	Academic Journal Article	https://doi.org/10.1177/00472875211037748
2022	Leuenberger, D. Z., & Lutte, R.	Sustainability, Gender Equity, and Air Transport: Planning a Stronger Future	Academic Journal Article	https://doi.org/10.1177/1087724X221075044
2022	Mendonca, F. A. C., & Keller, J.	Enhancing the Aeronautical Decision-Making Knowledge and Skills of General Aviation Pilots to Mitigate the Risk of Bird Strikes: A Quasi-Experimental Study	Academic Journal Article	https://orcid.org/0000-0001-7732-217X
2022	Sobieralski, J. B., & Mumbower, S.	Jet-setting during COVID-19: Environmental implications of the pandemic induced private aviation boom	Academic Journal Article	https://doi.org/10.1016/j.trip.2022.100575
2022	Stiebe, M.	Come Fly with Me (Sustainably): Pathways to Sustainable General Aviation and Private Pilot Training	Master's Thesis	http://urn.kb.se/resolve?urn=urn:nbn:se:hig:diva-39366
2022	Voipio, L.	eVTOLs and Pilot Training–The Impact of Electric Vertical Takeoff and Landing Aircrafts to Pilot Training	Master's Thesis	https://www.theseus.fi/bitstream/handle/10024/784636/Voip

				io_Lasse.pdf?sequence=2
2019	Kucuk Yilmaz, A., Flouris, T. G., Kucuk Yilmaz, A., & Flouris, T. G.	Introduction: Risks of the Multi-cultural Business Environment in Aviation Business. Values, Ergonomics and Risk Management in Aviation Business Strategy	Academic Book Chapter	https://doi.org/10.1007/978-981-15-1006-9
2016	Joubert, E., Chapuis, D., Esteyne, D., Lambert, J. C., Siri, O., & Müller-Wiesner, D.	The E-Fan all electrical aircraft demonstrator and its industrialization	Academic Conference Paper	https://www.icas.org/ICAS_ARCHIVE/ICAS2016/data/papers/2016_0731_paper.pdf
2014	Falcão, T. P., Luiz, R. R., Schütz, G. E., Mello, M. G. D. S., & Câmara, V. D. M.	Audiometric profile of civilian pilots according to noise exposure	Academic Journal Article	https://doi.org/10.1590%2FS0034-89102014048005256
1995	Truitt, L. J., & Tarry, S. E.	The rise and fall of general aviation: Product liability, market structure, and technological innovation	Academic Journal Article	https://www.jstor.org/stable/20713254

Appendix 3: Interview Guides for CFIs (German & English)

FLYING UNDER THE RADAR?

EDUCATION FOR SUSTAINABLE DEVELOPMENT IN PILOT TRAINING

Interviewleitfaden für Fluglehrer (DE)

I. Einleitung und Warm-Up:

- Wie geht es Ihnen heute?
- Vielen Dank, dass Sie sich heute Zeit genommen haben!

II. Teilnehmerinformation:

- Zusammenfassen der Ziele, Fragen und Umfang des Forschungsprojekts
- Erklären, wie die Interviewdaten verwendet werden
- Teilnehmer informieren über sein Recht, die Beantwortung von Fragen zu verweigern, und sein Recht, das Interview jederzeit abzubrechen und die Einwilligung jederzeit, auch nachträglich zu widerrufen
- Fragen, ob der Teilnehmer in Publikationen anonymisiert werden möchte
- Um die Zustimmung des Teilnehmers bitten, das Interview zur späteren Transkription und Auswertung aufzeichnen zu dürfen

Kategorie/Phase	*Frage*	*Follow-Up Fragen*	
1. Hintergrund	**1.1. Können Sie bitte ganz kurz etwas zu Ihre Person sagen? (Name, Alter, Beruf, Ausbildung)**		
	1.2. Wie und wann sind Sie zur Fliegerei gekommen?	1.2.1.	Wann und wo haben Sie Ihre PPL(A) und Ihren CFI gemacht?
	1.3. Warum fliegen Sie, was motiviert Sie?		
2. PPL(A) Ausbildung	**2.1. Was unterrichten Sie, Praxis und Theorie?**	2.1.1.	Welche Lernmaterialien verwenden Sie für die Ausbildung (z. B. BAK Ordner, GuV)
	2.2. Wie würden Sie Ihren pädagogischen Stil in theoretischer und praktischer Ausbildung beschreiben?	2.2.1.	Worauf legen Sie besonderen Wert?
	2.3. Könnten Sie bitte das zwischenmenschliche Verhältnis zu Ihren Flugschülern während der PPL(A) Ausbildungsphase beschreiben?	2.3.1.	

3.	*Nachhaltigkeit*	**3.1. Wie definieren Sie Nachhaltigkeit?**		
		3.2. Inwiefern spielt Nachhaltigkeit eine Rolle in Ihrem Leben? (z. B. in der Mobilität)	3.2.1.	Wie häufig machen Sie sich Gedanken um Nachhaltigkeit?
			3.2.2.	Auf welche Weise versuchen Sie nachhaltiger zu leben?
		3.3. Was sind aus Ihrer Sicht die aktuell wichtigsten Nachhaltigkeitsherausforderungen in der Privatpilotenausbildung?	3.3.1.	Inwiefern thematisieren Sie Nachhaltigkeitsthemen in der theoretischen und praktischen PPL(A) Ausbildung?
		3.4. Welche Rolle spielen Nachhaltigkeit und Umwelt in der theoretischen Flugausbildung?	3.4.1.	Inwieweit gibt es Fächer bei denen Nachhaltigkeit eine grössere oder kleinere Rolle spielt?
			3.4.2.	Wie sollte Nachhaltigkeit in der theoretischen Ausbildung thematisiert werden?
		3.5. Welche Rolle spielen Nachhaltigkeit und Umwelt in der praktischen Flugausbildung?	3.5.1.	Inwieweit gab es Ausbildungsphasen bei denen Nachhaltigkeit eine grössere oder kleinere Rolle spielt?
			3.5.2.	Wie sollte Nachhaltigkeit in der praktischen Ausbildung thematisiert werden?
		3.6. Inwiefern spiegeln sich die Umwelt- und Nachhaltigkeitsbedenken der jungen Flugschülergenerationen in der Flugausbildung ab?		
		3.7. Inwieweit spielt Nachhaltigkeit eine Rolle in Ihren privaten Flugaktivitäten?	3.7.1.	Welche Massnahmen ergreifen Sie, um nachhaltiger zu fliegen?
4.	*Vision*	**4.1. Wie stellst Sie sich eine nachhaltige PPL-Ausbildung in Zukunft vor?**		
5.	*Wrap-Up/ Verabschiedung*	**5.1. Gibt es noch etwas, dass Sie mir gern mitteilen möchten bezüglich Nachhaltigkeit in der PPL(A)-Ausbildung?**		

FLYING UNDER THE RADAR?

EDUCATION FOR SUSTAINABLE DEVELOPMENT IN PILOT TRAINING

Interview Guide for Certificated Flight Instructors (EN)

I. Introduction and warm-up:

- How are you today?
- Thank you for taking your time today!

II. Participant Information:

- Summarize the objectives, questions and scope of the research project
- Explain how the interview data is used
- Inform participants about their right to refuse to answer questions and their right to interrupt the interview at any time and to withdraw their consent at any time, including retrospectively
- Questions whether the participant would like to be anonymized in publications
- Ask for the participant's consent to record the interview for later transcription and evaluation

Category/Phase	*Question*	*Follow-up questions*	
1. Background	**1.1. Could you please say something about yourself? (name, age, occupation, education)**		
	1.2. How and when did you get into flying?	1.2.1.	When and where did you do your PPL(A) and CFI?
	1.3. Why do you fly, what motivates you?		
2. PPL(A) Training	**2.1. What do you teach, practice and theory?**	2.1.1.	What learning materials use for training (e.g. BAK folder, GuV)
	2.2. How would you describe your pedagogical style in theoretical and practical training?	2.2.1.	What do you attach particular importance to?
	2.3. Could you please describe the interpersonal relationship with your student pilots during the PPL(A) training phase?		
3. Sustainability	**3.1. How do you define sustainability?**		

		3.2. To what extent does sustainability play a role in your life? (e.g. in mobility)	3.2.1.	How often do you think about sustainability?
			3.2.2.	How do you try to live more sustainably?
		3.3. In your opinion, what are currently the most important sustainability challenges in private pilot training?	3.3.1.	To what extent do you address sustainability topics in the theoretical and practical PPL(A) training?
		3.4. What role do sustainability and the environment play in theoretical flight training?	3.4.1.	To what extent are there subjects in which sustainability plays a greater or lesser role?
			3.4.2.	How should sustainability be addressed in theoretical education?
		3.5. What role do sustainability and the environment play in practical flight training?	3.5.1.	To what extent have there been training phases in which sustainability plays a greater or lesser role ?
			3.5.2.	How should sustainability be addressed in practical training?
		3.6. To what extent are the environmental and sustainability concerns of the young generations of flight students reflected in flight training?		
		3.7. To what extent does sustainability play a role in your private aviation activities?	3.7.1.	What measures are you taking to fly more sustainably?
4.	***Vision***	**4.1. How do you imagine sustainable PPL training in the future?**		
5.	***Wrap-Up/ Farewell***	**5.1. Is there anything else you would like to tell me about sustainability in PPL(A) education?**		

Appendix 4: Interview Guides for Student Pilots (German & English)

FLYING UNDER THE RADAR?

EDUCATION FOR SUSTAINABLE DEVELOPMENT IN PILOT TRAINING

Interviewleitfaden für (frühere) Flugschüler (DE)

I. Einleitung und Warm-Up:

- Wie geht es dir heute?
- Vielen Dank, dass du dir heute Zeit genommen hast!

II. Teilnehmerinformation:

- Zusammenfassen der Ziele, Fragen und Umfang des Forschungsprojekts
- Erklären, wie die Interviewdaten verwendet werden
- Teilnehmer informieren über sein Recht, die Beantwortung von Fragen zu verweigern, und sein Recht, das Interview jederzeit abzubrechen und die Einwilligung jederzeit, auch nachträglich zu widerrufen
- Fragen, ob der Teilnehmer in Publikationen anonymisiert werden möchte
- Um die Zustimmung des Teilnehmers bitten, das Interview zur späteren Transkription und Auswertung aufzeichnen zu dürfen

Kategorie/Phase	*Frage*	*Follow-Up Fragen*	
6. Hintergrund	**6.1. Kannst du bitte ganz kurz was zu deiner Person sagen? (Name, Alter, Beruf, Ausbildung)**		
	6.2. Wie und wann bist du zur Fliegerei gekommen?	6.2.1.	Wann und wo hast du deine PPL(A) gemacht?
	6.3. Warum fliegst du, was motiviert dich?	6.3.1.	Wie willst du dich fliegerisch weiterbilden? (z. B. ATPL, CPL etc.)
7. PPL(A) Ausbildung	**7.1. Wie hast du die Flugtheorie gelernt? Distance Learning, Vor Ort?**	7.1.1.	Welche Lernmaterialien hast du verwendet? (z. B. BAK Ordner, GuV)

			7.1.2.	Wie war diese Lernerfahrung für dich?
			7.1.3.	Wie würdest du den pädagogischen Stil deiner Theorieinstruktoren beschreiben?
		7.2. Könntest du bitte das zwischenmenschliche Verhältnis zu deinem/n Fluglehrer/n während der PPL(A) Ausbildungsphase beschreiben?	7.2.1.	Wie war diese Lernerfahrung für dich?
			7.2.2.	Wie würdest du den pädagogischen Stil deines/deiner Fluglehrer/s beschreiben?
		7.3. Inwiefern wurde die Flugausbildung deinen Ansprüchen gerecht?	7.3.1.	Konntest du dich persönlich entwickeln und das Fliegen für dich «entdecken»?
8.	***Nachhaltigkeit***	**8.1. Wie definierst du Nachhaltigkeit?**		
		8.2. Inwiefern spielt Nachhaltigkeit eine Rolle in deinem Leben? (z. B. in der Mobilität)	8.2.1.	Wie häufig machst du dir Gedanken um Nachhaltigkeit?
			8.2.2.	Auf welche Weise versuchst du nachhaltiger zu leben?
		8.3. Was sind aus deiner Sicht die aktuell wichtigsten Nachhaltigkeitsherausforderungen in der Privatpilotenausbildung?		
		8.4. Welche Rolle haben Nachhaltigkeit und Umwelt in deiner theoretischen Flugausbildung gespielt?	8.4.1.	Inwieweit gab es Fächer und/oder Instruktoren bei denen Nachhaltigkeit eine grössere oder kleinere Rolle gespielt hat?
			8.4.2.	Wie sollte Nachhaltigkeit in der theoretischen Ausbildung besser thematisiert werden?
		8.5. Welche Rolle haben Nachhaltigkeit und Umwelt in deiner praktischen Flugausbildung gespielt?	8.5.1.	Inwieweit gab es Ausbildungsphasen oder Instruktoren bei denen Nachhaltigkeit eine grössere oder kleinere Rolle gespielt hat?
			8.5.2.	Wie sollte Nachhaltigkeit in der praktischen Ausbildung besser thematisiert werden?
		8.6. Welche persönlichen Bedenken hast du persönlich hinsichtlich Nachhaltigkeit in der General Aviation?	8.6.1.	Welche Sichtweisen bzgl. Nachhaltigkeit haben sich bei dir geändert vor/während/nach der PPL(A) Ausbildung?

		8.6.2.	Inwieweit spielt Flugscham oder ein schlechtes Gewissen vorm/beim/oder nach dem Fliegen für dich eine Rolle?
		8.6.3.	Welche Massnahmen ergreifst du, um nachhaltiger zu fliegen?
9. Vision	**9.1. Wie stellst du dir eine nachhaltige PPL-Ausbildung in Zukunft vor?**		
10. Wrap-Up/ Verabschiedung	**10.1. Gibt es noch etwas, dass du mir gern mitteilen möchtest bezüglich Nachhaltigkeit in der PPL(A)-Ausbildung?**		

FLYING UNDER THE RADAR?

EDUCATION FOR SUSTAINABLE DEVELOPMENT IN PILOT TRAINING

Interview Guide for (former) Student Pilots (EN)

I. Introduction and warm-up:

- How are you today?
- Thank you for taking your time today!

II. Participant Information:

- Summarize the objectives, questions and scope of the research project
- Explain how the interview data is used
- Inform participants about their right to refuse to answer questions and their right to interrupt the interview at any time and to withdraw their consent at any time, including retrospectively
- Questions whether the participant would like to be anonymized in publications
- Ask for the participant's consent to record the interview for later transcription and evaluation

Category/Phase	*Question*	*Follow-up questions*	
1. Background	**1.1. Can you please say something about yourself? (name, age, occupation, education)**		
	1.2. How and when did you get into flying?	1.2.1.	When and where did you do your PPL(A)?
	1.3. Why do you fly, what motivates you?	1.3.1.	How do you want to continue your flying education? (e.g. ATPL, CPL etc.)
2. PPL(A) Training	**2.1. How did you learn flight theory? Distance learning, on-site?**	2.1.1.	What learning materials did you use? (e.g. BAK folder, GuV)
		2.1.2.	How was this learning experience for you?
		2.1.3.	How would you describe the pedagogical style of your theory instructors?

		2.2. Could you please describe the interpersonal relationship with your flight instructor(s) during the PPL(A) training phase?	2.2.1.	How was this learning experience for you?
			2.2.2.	How would you describe the pedagogical style of your flight instructor(s)?
		2.3. To what extent did the flight training meet your requirements/expectations?	2.3.1.	Were you able to develop personally and «discover» flying for yourself?
3.	***Sustainability***	**3.1. How do you define sustainability?**		
		3.2. To what extent does sustainability play a role in your life? (e.g. in mobility)	3.2.1.	How often do you think about sustainability?
			3.2.2.	How do you try to live more sustainably?
		3.3. In your opinion, what are currently the most important sustainability challenges in private pilot training?		
		3.4. What role did sustainability and the environment play in your theoretical flight training?	3.4.1.	To what extent were there subjects and/or instructors in which sustainability played a greater or lesser role?
			3.4.2.	How should sustainability be better addressed in theoretical education?
		3.5. What role did sustainability and the environment play in your practical flight training?	3.5.1.	To what extent have there been training phases or instructors in which sustainability has played a greater or lesser role?
			3.5.2.	How should sustainability be better addressed in practical training?
		3.6. What personal concerns do you personally have regarding sustainability in general aviation?	3.6.1.	Which perspectives regarding sustainability have changed in your case before/during/after the PPL(A) training?
			3.6.2.	To what extent does flight shame or a guilty conscience before/during / after flying play a role for you?
			3.6.3.	What measures are you taking to fly more sustainably?
4.	***Vision***	**4.1. How do you imagine sustainable PPL training in the future?**		
5.	***Wrap-Up/ Farewell***	**5.1. Is there anything else you would like to tell me about sustainability in PPL(A) education?**		

Appendix 5: Interview Participant Consent Form

PARTICIPANT CONSENT FORM

UNIVERSITY OF GOTHENBURG

CONSENT TO TAKE PART IN RESEARCH:

FLYING UNDER THE RADAR? – EDUCATION FOR SUSTAINABLE DEVELOPMENT IN PILOT TRAINING

Purpose of the Study:
Through the lens of Education for Sustainable Development (ESD) and Transformational Learning Theory, this research seeks to contribute to the academic understanding of the roles of sustainability and sustainable development (SD) within the educational process of private pilot training (PPL(A)). This research is carried out for the primary purpose of obtaining the degree of Master of Science with a major in Education and Sustainability from the University of Gothenburg, Sweden. Besides a quantitative document analysis of pertinent PPL(A) education materials, a central part of this mixed-method research project are qualitative interviews with (recent) student pilots and certificated flight instructors which will last approximately 30 minutes each. You are cordially invited to share your opinions and experiences in such a semi-structured qualitative interview and make a contribution to sustainability research.

1. **I ..... voluntarily agree to participate in this research study.**
2. I understand that even if I agree to participate now, I can withdraw at any time or refuse to answer any question without any consequences of any kind.
3. I understand that I can withdraw permission to use data from my interview within two weeks after the interview, in which case the material will be deleted.
4. I have had the purpose of the study explained to me and had the opportunity to ask questions about the study.
5. I understand that I will not benefit directly from participating in this research.
6. I agree to my interview being audio-recorded.
7. I understand that all information I provide for this study will be treated confidentially.
8. I understand that in any report on the research results my identity will remain anonymous.
9. I understand that disguised extracts from my interview may be quoted in a master's thesis and other academic publications such as published journal and conference papers/presentations.
10. I understand that signed consent forms, original audio recordings, and a transcript of my interview in which all identifying information has been removed will be retained in an encrypted form on a physical hard drive until the thesis has been graded and/or related research papers have been published.
11. I understand that under freedom of information legalization I am entitled to access the information I have provided at any time while it is in storage as specified above.
12. I understand that I am free to contact the researcher to seek clarification and information.

Researcher and Affiliation: Michael Stiebe, M.Sc./M.A., (1) University of Gothenburg, Sweden, gusstiemi@student.gu.se; (2) Lucerne University of Applied Sciences and Arts HSLU, Switzerland, michael.stiebe@hslu.ch

Supervisor and Affiliation: Aimee Lee Haley, Ph.D., Senior Lecturer, Gothenburg University, Department of Education and Special Education / Faculty of Education, University of Gothenburg, Box 300, SE 405 30 Gothenburg, Sweden, aimee.haley@gu.se

Date, Signature of Research Participant ***Date, Signature of Researcher***

---------- ----------

Appendix 6: Thematic Analysis Codebook

Sustainability	Practical Learning	Practical Teaching	Theory Learning	Theory Teaching
Sustainability: Braking	Practical Learning: CFI Differences	Practical Teaching: Fuel Saving	Theory Learning: Learning Experience	Theory Teaching: Fuel Saving
Sustainability: Climate Change	Practical Learning: Electric Airplane	Practical Teaching: Interpersonal Relationship	Theory Learning: Learning Material	Theory Teaching: Gaps Regarding Sustainability
Sustainability: CO2 Compensation	Practical Learning: Exploration	Practical Teaching: Leaning and Mixing	Theory Learning: Role of Sustainability	Theory Teaching: Leaning and Mixing
Sustainability: CO2 Emissions	Practical Learning: Interpersonal Relationship	Practical Teaching: Motivation to Teach		Theory Teaching: Motivation to Teach
Sustainability: Concern	Practical Learning: Leaning and Mixing	Practical Teaching: Noise Abatement		Theory Teaching: Noise Abatement
Sustainability: Conservation of Resources	Practical Learning: Learning Experience	Practical Teaching: Role of Sustainability		Theory Teaching: Role of Sustainability
Sustainability: Definition	Practical Learning: Motivation for Flying	Practical Teaching: Student Interest in Sustainability		Theory Teaching: Teaching Material
Sustainability: Dimensions	Practical Learning: Obstacles to Sustainability	Practical Teaching: Syllabus		Theory Teaching: Teaching Style
Sustainability: Economy	Practical Learning: Perceptions of Sustainability	Practical Teaching: Teaching Style		Theory Teaching: Ways to Address Sustainability
Sustainability: Electric Airplane	Practical Learning: Role of Sustainability	Practical Teaching: Ways to Address Sustainability		
Sustainability: Environment	Practical Learning: Safety			
Sustainability: Environmental Conscience	Practical Learning: Simulator			
Sustainability: Fear	Practical Learning: Student Interest in Sustainability			
Sustainability: Flight Planning	Practical Learning: Syllabus			
Sustainability: Flight Shaming	Practical Learning: Transformational Change			
Sustainability: Flying Techniques				
Sustainability: Fuel Economy				
Sustainability: Gender				
Sustainability: Generational Differences				
Sustainability: Health				
Sustainability: Hydrogen Propulsion				
Sustainability: Issues and Challenges				
Sustainability: Leaded Fuel				
Sustainability: Leaning and Mixing				
Sustainability: Learning Material				
Sustainability: Noise				
Sustainability: Noise Abatement				
Sustainability: Personal Measures				
Sustainability: Potentials				
Sustainability: Preparation				
Sustainability: Role in Personal Life				
Sustainability: SDGs				
Sustainability: Social Sustainability				
Sustainability: Sustainable Aviation Fuel				
Sustainability: Technology				
Sustainability: Values				
Sustainability: Visions				