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Sustainable Space Travel: What Can We Do in Education from Economic and Environmental Perspectives?

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Abstract: Space travel began in 2001 and became popular in 2021 because of commercial operations. With the development of space technology and commercialization, like re-launchable rockets used to travel to space in recent years, hawse have gradually entered the space era. However, the space industry causes massive emissions, inducing some opposition to its development. It is essential to investigate the attitude of residents toward space travel and balance the pros and cons of sustainability. A quantitative analysis was adopted to test two models based on duality theory. The data were obtained from 284 samples from various regions of China and analyzed using partial least squares structural equation modeling (PLS-SEM). The results show that the two-factor model of economic development conflicted with environmental protection. However, study two indicates that educational interventions can facilitate sustainable space travel because they mediate the relationship between economic and environmental factors.

Keywords: sustainable space travel; economic development; environmental protection; education intervention; Chinese residents

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1. Introduction

"We are living out our childhood dreams"; the participants who experienced zero-gravity flight were full of praise [1]. Zero-gravity flights are only a small part of space travel that cannot be experienced in general tourism. Space tourism is commercial space travel that aims to provide travelers with unique experiences such as adventure, leisure, entertainment, weightlessness, and astronomical observation [2]. This study discusses the economic and environmental sustainability of space travel in addition to entertainment. Regarding the possible impact on the Earth's environment, this study excluded virtual and terrestrial space travel from the broad space travel market types of Laing and Crouch [3]. The three segments of space travel were discussed: near space, suborbital, and low orbit/high orbit. The sustainability, long-term survival, and development initiatives and actions of the space travel industry are also a central research theme, which is discussed based on the three bottom lines model of economic, social, and environmental aspects [4].

Space tourism began with Dennis Tito's trip to the International Space Station in 2001, and from 2001 to 2009, only eight travelers entered space at a cost of approximately USD 20 million to USD 35 million [5]. Since 2021, space travel has boomed, with Virgin Galactic alone sending three successful flights for space travel from June to September 2023. The company has already sent more than 16 travelers into space. In the current commercial development of space travel, a number of private companies from the United States and China, led by SpaceX and Blue Origin, have achieved more significant growth in recent years. Detailed information can be found in Appendix B. According to a conservative business strategy analysis, suborbital space travel alone has an expected net present value of at least USD 2 billion, which will undoubtedly significantly boost economic development [6].

However, space travel may cause severe environmental impacts as the scale expands. For example, the black soot left behind by the insufficient combustion of aircraft fuel may reduce the local temperature by 0.7 degrees Celsius and increase the average temperature in Antarctica by 0.8 degrees Celsius. This black soot will stay in the stratosphere for 5–10 years [7]. Carbon dioxide (CO_2) emissions are also issues caused by the space industry.

Environmental pollution caused by human activities is not irremediable. The satellites we have launched into space have recorded the ecological destruction of melting glaciers, the reduction in forests, the hole in the ozone layer, and the desertification of land caused by various human actions [8]. Before it is too late to take remedial measures, we can minimize the environmental harm by taking sustainable measures. For example, restricting the use of chlorofluorocarbon chemicals can cause the ozone layer to return to pre-1980 levels in 2030 [9]. We should be aware of the possible consequences of specific actions earlier. We should prepare earlier to ensure environmental sustainability is achieved, including space travel activities. Although environmental protection and economic development are often part of a dilemma in which both cannot be achieved, sustainability education may help to improve this contradictory relationship [10]. The role of education in promoting the spread of sustainable concepts has been quantitatively proven [11].

Sustainable space travel must be actively discussed scientifically and collaborated among practitioners, government officials, investors, residents, and educators. Thus, this study aims to (a) investigate the attitudes of Chinese residents toward space travel and sustainability; (b) construct a model for economic development and environmental sustainability in space travel; and (c) explore the intervention effect of education on sustainable development toward a holistic development of sustainable space travel.

2. Theoretical Foundation and Hypotheses Development

2.1. Duality Theory: Factors of Economic Development and Environmental Protection

The duality theory is applied to examine mutually deterministic relationships involving multiple aspects. The dyadic relationship can happen between output and cost, as well as between utility and expenditure, which are typical applications in economics. Economic development and environmental protection are considered to have a dyadic relationship in our society, and there is a clear relationship between the various behaviors that protect the environment and the inhibition of economic development [12]. Duality theory is applied in this study to interpret the optimization model of the dual factors, economic development and environmental protection, which is sustainability [13]. Sustainable space travel is the research objective, moving from conflict to coherent dual factors. Since 1960, researchers have often discussed economic development and environmental protection with the main arguments on the binary opposition [14,15]. Some claim that GDP growth slows down because of environmental protection measures. Stakeholders then revisit the significance of economic growth. GDP fetishism has been widely criticized as a very narrow way to judge the standard of living concerning the environmental population, and its significance in indicating economic growth is limited without sustainability [16]. Researchers have argued the need to use a more multifaceted approach to understand economic development, including discussions of residents' attitudes [17]. Residents' perceptions of environmental protection have been studied extensively, and our actions have not always been effective in curbing ecological decline after it was realized that economic development would be damaging to the environment [18].

When we talk about the traditional contradiction between economic development and environmental protection from the standpoint of residents' attitudes, the discussion of balancing the two is missing. Researchers have always used leading dichotomous survey questions, such as, "Should protecting the environment be prioritized, even if it inhibits the risk of economic growth, or should economic growth be prioritized, even if the environment is damaged to some degree?" [19]. Kaplowitz et al. [20] suggest introducing more pluralistic attitudes in studying economic growth and environmental protection. Thus, this paper discusses and advances space travel development from the sustainability perspective.

Some companies have taken a negative attitude toward environmental protection, and incidents of "greenwashing" have become commonplace in recent years. Even some "green" behaviors may be contributing to the development of a new consumerism while doing little to change the present and future of humanity. We are also looking for more down-to-earth approaches, such as educational interventions, to shape people's perceptions of sustainable development more thoroughly and scientifically.

In addition to the discussion of the economy and the environment, Alhaddi [21] also suggests the use of the triple bottom line (TBL) to help build a complete theory related to sustainability, which we use as a theoretical foundation for the sustainability discussion. That is, based on social, environmental, and economic lines, "development that meets the needs of the present generations without compromising the ability of the future generations to meet their own needs".

2.2. Space Travel Industry and Environmental Sustainability

The space travel program was first launched in 2001, and the development of space travel was initially intended to serve countries' political interests, with commercialization being secondary [22]. However, as more and more countries enter the space field for cosmological and commercial explorations, people are gradually realizing the importance of developing the space economy under the premise of non-aggression, and the space travel industry has become one of the emerging businesses [23]. Space travel belongs to the category of experiential tourism. It is the use of high technology to send passengers to space or space-related areas for short-term travel activities for leisure purposes. There is no specific destination to stay, and tourists' activities are limited to the spacecraft so far [24]. Specifically, space travel mainly includes four types: orbital flight, suborbital flight, high-altitude flight near space, and parabolic aircraft flight [25,26]. The history of the development of space travel is illustrated in Figure 1 and is described in Appendix A.

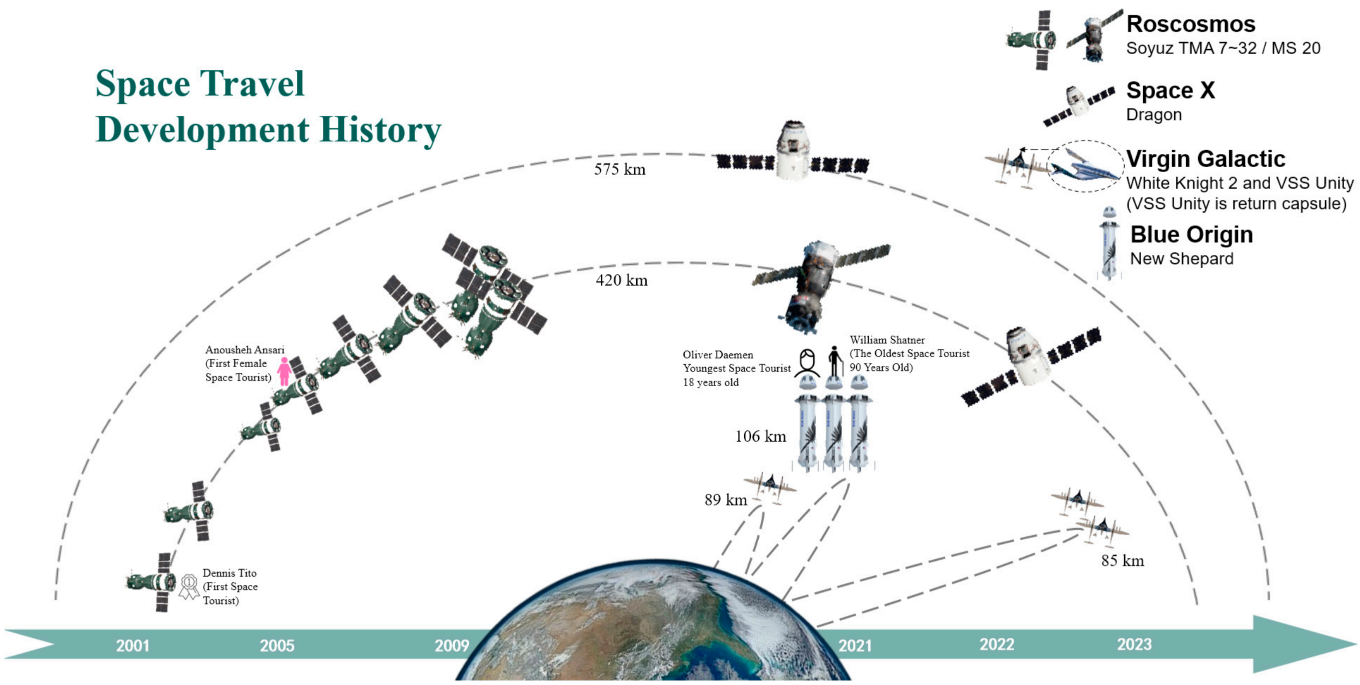

Figure 1. Space travel history. Note: This figure shows relevant space enterprises (excluding agents) that have used self-developed rockets to go into space. The spacecraft's size represents that trip's cost (non-standard ratio). In the development of the space travel industry, there are many problems, such as high flight ticket prices, lack of legal protection and uniform regulations, uncertain launch safety factors, high physical fitness requirements for participants, and environmental pollution [27,28]. In addition, there are differences between traditional territorial tourism and current space travel. The

imbalance between supply and demand exists in space travel due to the high supply-side technology and capital threshold requirements, as well as corresponding restrictions on consumers' financial and physical conditions.

However, we cannot deny that the development trend of space travel is positive. Cole [29] pointed out in his research that although space travel will develop slowly in the short term due to the immature level of science and technology and the mismatch of the per capita disposable income, it is still in line with the tourism life cycle theory, and it will eventually become a mass tourism business to form a maturity market with considerable economic benefits. Launius and Jenkins [30] believed that explorers with great wealth are critical in the early stages of space travel. However, mass tourists should have affordable and comfortable travel opportunities in the next ten years. With the development of science and technology, space flight will eventually become as popular in human society as airplanes. Considering the potential and influence of space travel, we can foresee its positive impact on human social and economic development, scientific education, cultural inheritance, and residents' employment in the future [31]. Space travel literature mainly focuses on space laws, consumers' tourism motivation, and sustainable space travel [32–37].

With the current fuel-related technology, space travel, if scaled up rapidly, would have a rather severe emissions problem. Not to mention, the energy consumption of an airplane that travels 100 times the distance traveled for the same flight and the black smoke and fuel from inadequate combustion would affect the regional atmosphere. Propellants used in rockets are also emitted into the atmosphere. SpaceX currently uses the nitrogen tetroxide (NTO)/monomethyl hydrazine (MMH) bipropellant combination as the propellant for Dragon 2. MMH is widely detected in groundwater and is a severe contaminant of water bodies. Qian et al. [38] used the preparation of composite materials as activators to clean up MMH contamination. The decomposition product of NTO, nitrogen dioxide (NO_2), is also a major atmospheric pollutant, and NO_2 significantly impacts the atmospheric chemistry (formation of tropospheric ozone). Environmental pollution issues then arouse our awareness and encourage us to take action for sustainable space economics. The traditional selective catalytic reduction technology requires high reaction temperatures. New technologies use sponge-like aluminum-based solid porous nanomaterials placed in the center of porphyrin rings to selectively capture and remove NO_2 from gas mixtures [39]. As governments and corporations focus on advanced technology, spacecraft also increasingly use fewer polluting fuels. Emission limits are advocates for space travel. Technological advances related to cleaner and harmless fuels are applied. This is not only carried out for environmental conservation, but also for the sustainability of the space travel industry.

In summary, we propose the following hypotheses:

H_1: *Economic development is a driving force for space travel development*.

H_2: *Economic development has an adverse influence on environmental sustainability*.

H_3: *Environmental protection has a negative impact on space travel development*.

H_4: *Environmental protection is a driving force to environmental sustainability*.

2.3. Sustainable Space Travel with Two Factors

The space travel industry includes space travel hotels, space insurance, space medical care, and other supporting industries that collaborate to create warfare for human beings. In addition to the environmental awareness for the space industry, risk reduction for passengers is an inevitable issue. When carrying out space travel, passengers will face psychological risks, physical health risks, and economic risks [40]. Creating a viable and affordable insurance system for future tourists is essential in marketizing space travel [41]. Commercial satellite data applications may also be a vital stream in the industry [42]. When space travel is successfully popularized, related space medical activities (including pre-flight physical examinations, physical training for passengers, and post-flight physical abnormality investigations) are also expected to form a complete industrial chain [43]. It is worth pondering that space industry development must be responsible for human beings, providing economic output and long-term environmental benefits. A sustainable space economy should resolve the ecological issues of commercial satellite operations, space travel, lunar and asteroid mining, and other development forms of the space industry. When the space economy can operate efficiently and in an environmentally friendly way, the high technological costs of space exploration will benefit generations. Science and technology should play vital roles in promoting the co-development of economic development and environmental conservation [44].

Pollution emissions from space travel are not negligible. One of the solutions is to tax the emissions of CO_2. The CO_2 tax could be levied on any other greenhouse gas and can usually be converted to an amount equivalent to CO_2 emissions. For example, aviation kerosene fuel, which is currently used regularly, emits 3.03 tons of CO_2 per ton of fuel [45]. Currently, a CO_2 tax is the least costly and feasible way to reduce emissions, and revenue from the tax is generally used for low-income groups, which indirectly maintains social equality [46]. Other rockets that use liquid oxygen and liquid hydrogen fuel do not generate CO_2, and thus, their carbon emissions will not be considered.

We must realize that the sustainable development of space is not the responsibility of a nation or region, but an important topic that all of humanity must be involved in. Treating space debris has always been a problem that we have not adequately addressed as we develop our space industry. Every satellite sent into space can become space debris when broken or retired, polluting the space environment and threatening the safety of all flying objects in orbit [47]. There are currently two mainstream solutions for space debris mitigation. The first solution is for spacecraft to actively seek to release orbital space by de-orbit after completing a mission. The second is to extend the life of existing spacecraft and reduce the number of spacecraft launches to minimize the generation of new debris [48]. In addition to orbital debris, there is an inevitable creation of a large amount of space junk, such as abandoned satellites, remnants of rocket thrusters, and small debris from collisions of various materials in space during human operations in outer space. The manner in which space debris is cleaned up is referred to in Appendix C. Leonard and Williams [49] pointed out that the sustainable use of space debris and space junk is feasible, and the development of in-orbit services is the key to solving the problem of such debris. This is based on the fact that the cost of recycling and reusing aircraft launch equipment is gradually decreasing, and the benefits of each launch are higher than the cost of cleaning debris. Heinrich et al. [50] proposed establishing professional space sustainability rating standards to regulate the growing number of new space operators. This is a plan to limit enterprises' uncontrolled spacecraft launches to regulate the metabolic balance of old and new space debris.

When discussing the protection of the space environment, we should not only try to solve the problem of space debris but also pay attention to educating the population [51]. Many scholars have suggested different views regarding the sustainable development of space travel. Toivonen [52] proposed a framework for "social ethics in space travel", which includes the development of virtual space travel using VR technology, specialized environmental protection actions, the development of global space laws, and the shaping of Generation Z's values. Although virtual reality technology cannot replace real tourism activities, it can go some way to fulfill people's tourism needs and reduce the damage caused by nature-based tourism activities, especially space travel [53]. Peeters [54] argues that point-to-point regular space travel development will be a future direction for sustainable space travel.

There is a view that space travel is not inherently compatible with sustainable tourism needs. Instead of developing this elite-class recreational activity at the expense of damaging the environment, the relevant resources should be used to take action to address climate change [34]. Meanwhile, as space travel itself is still in the nascent stage, this tourism activity can only be offered to wealthy tourists to experience, and it is difficult for general people to pay such a high cost. Benjamin [55] points out that, in the future, the space travel industry will likely form an oligopoly and maintain the status quo of high fares, where people only have the right to choose the form of their experience dominated by the suppliers. The legal issues involved in space travel are fragmented. The international legal system of outer space is still immature, with many deficiencies, and space travel is controversial because it may violate national airspace security during flight [56].

From a positive point of view, some people believe that if they can experience space travel, it will be an unforgettable experience of a lifetime, and they may even become heroes in human history [57]. Overall, space travel is an inevitable direction for the future development of tourism, but it requires the efforts of its development with sustainability. As mentioned above, the challenges of sustainable space travel are the dual factors of economic growth and environmental conservation, which need to be considered.

So, we propose the following hypotheses:

H_5: *Economic development is a positive drive to sustainable space travel.*

H_6: *Environmental protection has a positive influence on sustainable space travel.*

2.4. Educational Intervention for Sustainability

Exploring outer space fulfills the highest needs level of human beings, so developing space travel has become an inevitable trend [58]. Implementing space travel activities will inevitably cause a massive amount of environmental pollution. This will cause ecological problems, involving social, economic, cultural, scientific, and technological factors. Our current science and technology cannot wholly solve the pollution problem, but we can consciously educate the next generations to be aware of the issues and devote their creativity to sustainable space travel.

The best way to promote the conscious participation of all of humankind in environmental protection activities is through education [59]. Education can affect people's behavior, and the influence of pro-environment-related consumption behavior is particularly significant [60]. The implementation of sustainable action can be carried out through education. It can cultivate the concept of personal, environmental, and sustainable development. Educational interventions can attain the goal of sustainability [61]. Through systematic education, students can learn to understand and evaluate a series of sustainable activities in society from a scientific perspective, rethink the relationship between humans and nature, and take responsibility for the sustainable development of human society [62]. Environmental education can also guide people to apply replicable ecological research results to their lives and solve stakeholders' environmental problems together [63]. Therefore, education is indispensable to both economic development and environmental protection.

The intervention form of education is often carried out through experimental methods. Through experiments, Miriam Andrea, Jesus, Isaac, and Andrea et al. [64] demonstrated that professional teaching methods can mobilize people's attitudes and awareness of sustainable development, influencing their willingness to take action in the future. Stevens et al. [65] found that storytelling during tourism education develops the ethical level of the listener, which, in turn, helps the learner think better about forms of harmonious coexistence between humans and nature. With space travel's further development and requirements, pilots must acquire specific tour guide skills [37]. Pilots can carry out corresponding tourism education activities when passengers look at the Earth's landscape and marvel at the fragility and beauty of this blue planet, and they can deepen tourists' awareness of environmental protection through storytelling. Arslan [66] found that sustainable education fosters students' environmental awareness, promotes the growth of critical thinking, and helps them think about problems from different perspectives. This development of critical thinking helps people look at the development of space travel activities correctly so that people can see not only the damage that space travel causes to the environment but also the various resource returns that space exploration activities bring. This is the significance of educational interventions as a mediator and why they may influence inhabitants' perception of sustainable space travel. So, we can derive the following hypotheses:

H_7: *Economic development triggers a positive awareness of educational interventions.*

H_8: *Environmental protection triggers a positive awareness of educational interventions.*

H_9: *Educational intervention has a positive effect on sustainable space travel.*

H_{10}: *Educational intervention mediates economic development and sustainable space travel.*

H_{11}: *Educational intervention mediates environmental protection and sustainable space travel.*

3. Methodology

3.1. Sampling and Data Collection

We construct competing models from the dual factors of economic development and environmental conservation. Model 1 in Figure 2 shows a general perspective that economic development positively drives the development of the space travel industry but negatively impacts sustainability, and while environmental protection positively influences sustainability, it negatively affects the development of the space travel industry. Model 2 assumes that educational intervention triggers a mediating effect between the two constructs of space travel and environmental protection to attain the goal of sustainable space travel. This means that education plays an essential and positive role in promoting sustainability in space travel.

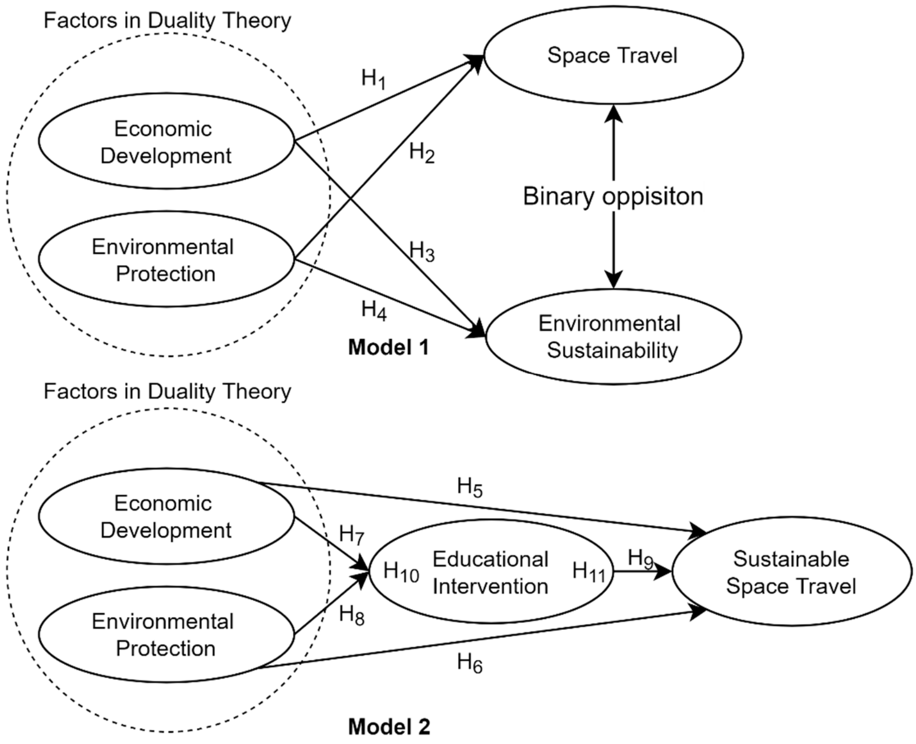

Figure 2. Conceptual model (Study 1: top; Study 2: down).

3.2. Measurement Items

The measurement items were derived from the literature and modified according to the research models. We used four items from Drews and van den Bergh (2016) about residents' views to measure economic development and environmental protection. The classic New Environmental Paradigm (NEP) scale was used to investigate residents' views on environmental protection. These four items were selected and adapted from the scale created by Dunlap et al. [67]. To measure the development of the space travel industry, we combined the views of many scholars on the space travel economy and industry and proposed four items [31,68,69]. We selected four items from different aspects of the sustainability scale of Haan et al. [70] to investigate residents' views on environmental sustainability.

Regarding the difference between "environmental protection" and "environmental sustainability", researchers believe that the impacts of human development on the environment can be compensated for through a variety of behaviors that lead to sustainable natural resource use, balancing the protection of nature with the need for development. Environmental sustainability combines conservation and development rather than a single direction of environmental protection alone.

We developed four educational intervention items through the United Nations' guidance document on sustainable education development [71]. Finally, based on the literature on sustainable space travel, we developed four items for sustainable space travel [52,72]. Each of the four environmental protection and sustainability items uses reverse questioning to screen whether the samples are valid [73]. The measurement items are shown in Table 1.

Table 1. Measurement items.

	Item
	Economic Development
ED1	Economic growth is necessary to increase employment opportunities.
ED2	Without economic growth, a better life is challenging to achieve.
ED3	Sustained economic growth can improve people's life satisfaction.
ED4	Without economic growth, the economy will become less stable.
	Environmental Protection
EP1	The Earth has unlimited resources for human use.
EP2	Human intervention will naturally not have disastrous consequences.
EP3	Nature's self-balancing ability can cope with the destruction of modern industry.
EP4	Human beings are special and can transcend all natural laws.
	Space Travel
ST1	Space travel is a direction of tourism development.
ST2	Space travel can drive economic development.
ST3	Space travel can help humanity get out of its resource dilemma.
ST4	Traveling to space is worth my time and energy.
	Environmental Sustainability
ES1	Going the extra mile to be environmentally sustainable is unnecessary.
ES2	Humans do not need to care about environmental sustainability deliberately.
ES3	Producing and selling organic food is not environmentally sustainable.
ES4	Companies that maintain environmental sustainability should not deserve additional subsidies.
	Educational Intervention
EI1	I am willing to learn about sustainability.
EI2	I want to learn about sustainable practices.
EI3	I learned that I should take responsibility for sustainable development.
EI4	I will apply sustainable knowledge in my life.
	Sustainable Space Travel
SST1	Space travel enterprises should provide long-term stable business profitability.
SST2	Space travel should be carbon neutral through various means.
SST3	Space travel enterprises should provide long-term and stable employment opportunities.
SST4	Space travel should allow tourists to have an unforgettable space experience.

3.3. Sampling Method

This study used an online platform (Tencent Questionnaire) to collect samples. The Tencent Questionnaire has a high-quality sample database of over 3 million people and high sample validity [74]. It mainly sent questionnaires through WeChat, which has over 1.3 billion active users. The responses from Chinese residents were counted in October 2023, and participants who provided valid answers were awarded CNY 3. Participants were asked to read a paragraph about space travel and sustainable space travel and then answer the questionnaire items. The average completion time was 3 min and 36 s. A total of 367 samples were collected. After excluding two people with IP addresses outside of China, deleting 16 questionnaires claiming to be minors, deleting questionnaires that took insufficient time to answer (less than 65 s), and failing responses to reverse questions, 284 questionnaires remained (77.4%). The research questions in the questionnaire included a total of 24 items. Structural equation modeling was used to validate both models. This study uses structural equation modeling (SEM), and the sample size should be 5–10 times the number of questionnaire items. The sample size is proper according to the data collected [75].

4. Results and Discussion

4.1. Sample Profile

The results of the descriptive analysis are shown in Table 2. In the survey, 41.9% of the respondents were male, and 58.1% were female. The ages of the respondents were 18–24 years old (59.9%), 24–30 years old (22.9%), 31–40 years old (11.6%), 41–50 years old (2.8%), 51–60 years old (2.1%), and over 60 years old (0.7%). Many respondents completed a college degree (72.9%), with a high school degree or less (11.3%). The numbers of people with incomes of less than CNY 2500 (26.1%), CNY 2501–5000 (28.9%), and CNY 5001–10,000 (28.2%) were similar and accounted for the majority. The proportion of people with incomes above CNY 10,000 was not too low (16.9%). There was no bias observed in the sample distribution.

Table 2. Sample profile (n = 284).

Characteristics	Frequency	Percentage %
Gender		
Male	119	41.9
Female	165	58.1
Age		
18–24	170	59.9
25–30	65	22.9
31–40	33	11.6
41–50	8	2.8
51–60	6	2.1
>60	2	0.7
Education		
Secondary school or below	32	11.3
Diploma and university degree	207	72.9
Master's degree	40	14.1
PhD	5	1.8
Income (RMB)		
<2500	74	26.1
2501–5000	82	28.9
5001–10,000	80	28.2
10,001–15,000	30	10.6
15,001–20,000	7	2.5
>20,000	11	3.9

The sample covers 29 of China's 34 provincial administrations (it is only missing samples from Qinghai Province, Tibet Autonomous Region, Xinjiang Uygur Autonomous Region, Taiwan Province, and Hong Kong Special Administrative Region), making it more representative of China regarding regional distribution.

4.2. Measurement Model

In this study, economic development and environmental protection are independent variables. In contrast, space travel, environmental sustainability, educational intervention, and sustainable space travel are dependent variables, and educational intervention is the mediating variable. To ensure the credibility and accuracy of the results, the reliability test was conducted using Cronbach's α and composite reliability (CR). The factor loadings of all variables in Tables 3 and 4 are bigger than 0.6 (range from 0.655–0.912), the Cronbach's α is > 0.7 (range from 0.713–0.933), and the CR is >0.8 (range from 0.823–0.933), with a good confidence level [76]. The validity of the questionnaire was determined through the content validity and construct validity. We solicited opinions from space travel literature and interviews with experts and professors to confirm the content validity. The construct validity was measured using a confirmatory factor analysis (CFA) and convergent and divergent validity. The average variance extracted (AVE) index was used to test the convergent validity. The convergent validity was qualified for AVE > 0.5 (range from 0.538 to 0.822). The VIF value of EI2 was greater than 5, so this item was deleted. After the item analysis, all VIF values were < 3.3 (range from 1.242 to 2.661), indicating that there was no (multi) collinearity problem [77].

Table 3. Measurement model analysis (Model 1).

Variable	Items	Mean	STDEV	Factor Loadings	VIF	Cronbach α	CR	AVE
ED	ED1	6.08	1.043	0.802	1.458	0.775	0.853	0.593
	ED2	5.94	1.222	0.756	1.460			
	ED3	5.99	1.077	0.748	1.541			
	ED4	5.4	1.417	0.773	1.624			
ST	ST1	5.51	1.4	0.843	1.875	0.828	0.883	0.654
	ST2	4.93	1.511	0.858	1.981			
	ST3	4.88	1.488	0.811	1.672			
	ST4	4.53	1.782	0.717	1.617			
EP	EP1	1.68	1.095	0.722	1.336	0.751	0.843	0.574
	EP2	1.72	1.173	0.718	1.345			
	EP3	1.85	1.25	0.811	1.662			
	EP4	1.45	0.97	0.775	1.519			
ES	ES1	1.59	1.196	0.799	1.483	0.713	0.823	0.538
	ES2	1.61	1.255	0.758	1.461			
	ES3	2.62	1.572	0.655	1.242			
	ES4	1.83	1.157	0.715	1.323			

Table 4. Measurement model analysis (Model 2).

Variable	Items	Mean	STDEV	Factor Loadings	VIF	Cronbach α	CR	AVE
ED	ED1	6.08	1.043	0.835	1.458	0.775	0.851	0.588
	ED2	5.94	1.222	0.712	1.460			
	ED3	5.99	1.077	0.768	1.541			
	ED4	5.40	1.417	0.747	1.624			
*EP**	EP1	6.32	1.095	0.732	1.336	0.751	0.842	0.571
	EP2	6.28	1.173	0.750	1.345			
	EP3	6.15	1.250	0.782	1.662			
	EP4	6.55	0.970	0.758	1.519			
EI	EI1	6.03	1.151	0.897	2.599	0.892	0.933	0.822
	EI3	5.98	1.172	0.911	2.661			
	EI4	6.04	1.103	0.912	2.656			
SST	SST1	4.88	1.383	0.804	2.045	0.844	0.896	0.683
	SST2	5.42	1.390	0.829	1.848			
	SST3	5.08	1.473	0.883	2.649			
	SST4	5.86	1.294	0.785	1.613			

Note: The construct *EP** was reversed in study 2.

This study used the Fornell–Larcker criterion and the heterotrait/monotrait ratio (HTMT) to verify the differential validity. The Fornell–Larcker criterion stipulates that the square root of the AVE should be higher than the inter-structure correlation [78]. Tables 5 and 6 present the results for Model 1 and Model 2, respectively, with diagonal values higher than those below. The HTMT value (range from 0.139 to 0.788) is lower than the threshold of 0.85, and overall, the discriminant validity meets the standard [79].

Table 5. Discriminant validity (Model 1).

	ED	*EP*	*ES*	*ST*
ED	**0.770**	0.321	0.389	0.445
EP	−0.266	**0.758**	0.788	0.139
ES	−0.308	0.580	**0.734**	0.213
ST	0.383	−0.087	−0.168	**0.809**

Note: Underline font: heterotrait/monotrait ratio; bold font: square root of the AVE.

Table 6. Discriminant validity (Model 2).

	ED	*EP*	*EI*	*SST*
ED	**0.767**	0.321	0.397	0.375
EP	0.274	**0.756**	0.425	0.155
EI	0.350	0.356	**0.907**	0.563
SST	0.327	0.128	0.492	**0.826**

Note: Underline font: heterotrait/monotrait ratio; bold font: square root of the AVE.

4.3. Structural Measurement Model

Partial least squares structural equation modeling (PLS-SEM) was used to test the research model (Figures 3 and 4 show the results of this study) because PLS can handle small samples and has greater confidence in the normal distribution of the data. There were few restrictions [80]. The SmartPLS V.4.0.9.5 software package was used, and bootstrapping was performed using 5000 samples to evaluate the path coefficients [81].

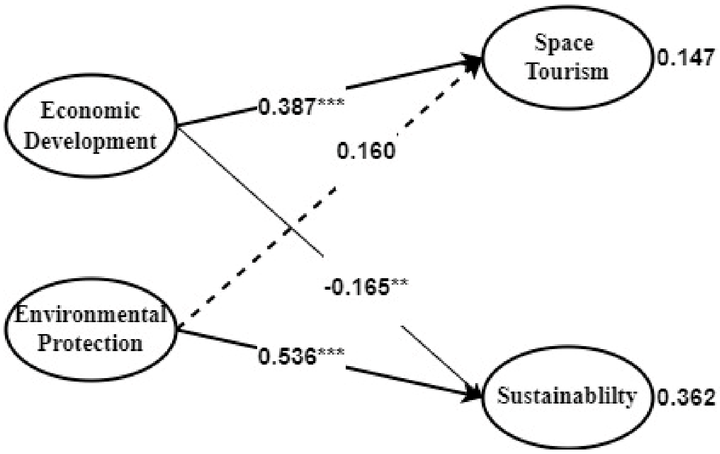

Figure 3. Result of PLS-SEM (Study 1). Note: **: $p < 0.01$, ***: $p < 0.001$, no asterisk: $p > 0.05$. The number near the construct: R^2.

Structural models are evaluated using multiple criteria, including the model's explanatory power (R^2), path coefficient (b), t-value, and *p*-value [80]. As a general guideline, an R^2 value of 0.25 is weak, 0.50 is moderate, and 0.75 is substantial. According to Cohen [82], the R^2 value can be evaluated as substantial (0.26), moderate (0.13, and weak (0.02). If this criterion is used, the results show that the space travel industry has an R^2 value of 0.147. The R^2 value for environmental sustainability is 0.362, indicating that these factors explain 36.2% of the variance. In Study 2, the R^2 value for the educational intervention was 0.196, and the R^2 value for the sustainable space travel industry was 0.276. The model explanatory degree is moderate and substantial, and the explanatory power is good. The results of the PLS prediction are shown in Table 7. According to the suggestion by Hair et al. [83], only the prediction errors of the endogenous variables are shown, with $Q^2 > 0$, the vast majority of $RMSE_{PLS\text{-}SEM—LM} < 0$, and the prediction ability is good.

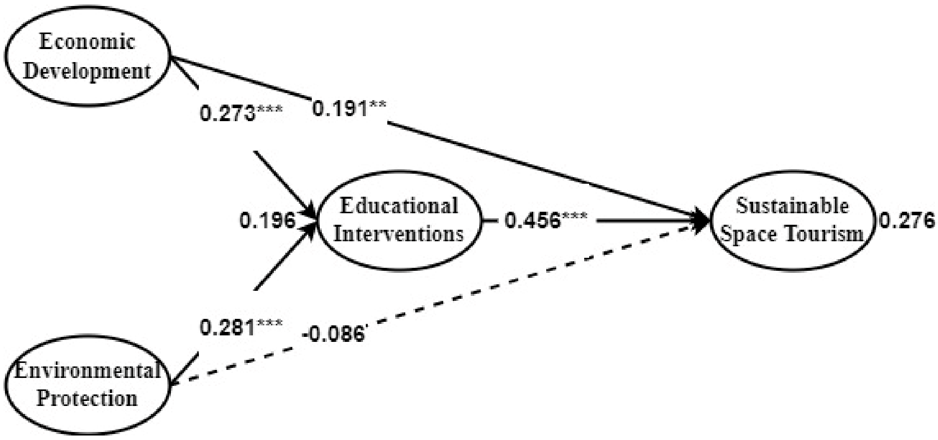

Figure 4. Result of PLS-SEM (Study 2). Note: **: $p < 0.01$, ***: $p < 0.001$, no asterisk: $p > 0.05$. The number near the construct: R^2.

Table 7. Results for SmartPLS (k = 10).

		Model 1		
	PLS-SEM		**LM**	**PLS-SEM—LM**
Item	**Q^2 Predict**	**RMSE**	**RMSE**	**RMSE**
ES1	0.250	1.037	1.066	−0.029
ES2	0.170	1.146	1.172	−0.026
ES3	0.137	1.463	1.473	−0.010
ES4	0.161	1.061	1.090	−0.029
ST1	0.100	1.332	1.317	0.015
ST2	0.111	1.427	1.455	−0.028
ST3	0.095	1.418	1.440	−0.022
ST4	0.008	1.778	1.786	−0.008
		Model 2		
	PLS-SEM		**LM**	**PLS-SEM—LM**
Item	**Q^2 Predict**	**RMSE**	**RMSE**	**RMSE**
EI1	0.096	1.095	1.106	−0.011
EI3	0.157	1.078	1.104	−0.026
EI4	0.168	1.008	1.023	−0.015
SST1	0.049	1.351	1.350	0.001
SST2	0.031	1.371	1.379	−0.008
SST3	0.056	1.434	1.448	−0.014
SST4	0.102	1.228	1.238	−0.010

Table 8 also presents the results of the hypothesis testing in Model 1 and Model 2. Hypothesis 1 illustrates the positive impact of economic development on space travel. H_1 was supported ($\beta_{ED\rightarrow ST} = 0.690$, $p < 0.001$). Hypothesis 2 describes the negative impact of economic development on environmental sustainability. The results show that economic development significantly negatively impacts environmental sustainability ($\beta_{ED\rightarrow ES} = -0.165$, $p < 0.01$). Therefore, H_2 was supported. Hypothesis 3 states that environmental protection harms space travel. However, as seen from the results, H_3 was not supported

($\beta_{EP\rightarrow ST}$ = 0.016, $p > 0.05$). H_4, the positive impact of environmental protection on environmental sustainability, was supported ($\beta_{EP\rightarrow ES}$ = 0.536, $p < 0.001$). H_5, the positive impact of economic development on sustainable space travel, was supported ($\beta_{ED\rightarrow SST}$ = 0.189, $p < 0.01$). However, H_6, which states the impact of environmental protection on sustainable space travel, was not supported ($\beta_{EP\rightarrow SST}$ = −0.085, $p > 0.05$). H_7 and H_8, the positive effects of economic development and environmental protection on educational intervention, are supported ($\beta_{ED\rightarrow EI}$ = 0.279, $p < 0.001$; $\beta_{EP\rightarrow EI}$ = 0.278, $p < 0.001$). H_9, the positive impact of educational intervention on sustainable space travel, is supported ($\beta_{EI\rightarrow SST}$ = 0.455, $p < 0.001$).

Table 8. Results for PLS-SEM analysis.

Model 1						
Hypotheses	**Path**	**Standard Beta**	**t-Value**	***p*-Value**	**f-Squire**	**Decision**
H_1	ED→ST	0.387	7.727	0.000	0.163	Supported
H_2	ED→ES	−0.165	3.016	0.003	0.040	Supported
H_3	EP→ST	0.016	0.275	0.783	0.000	Not supported
H_4	EP→ES	0.536	8.633	0.000	0.419	Supported
Model 2						
Hypotheses	**Path**	**Standard Beta**	**t-Value**	***p*-Value**	**f-Squire**	**Decision**
H_5	ED→SST	0.191	3.218	0.001	0.043	Supported
H_6	EP→SST	−0.086	1.652	0.099	0.009	Not supported
H_7	ED→EI	0.273	4.878	0.000	0.086	Supported
H_8	EI→SST	0.456	6.558	0.000	0.231	Supported
H_9	EP→EI	0.281	4.870	0.000	0.091	Supported

4.4. The Mediating Effect of Educational Intervention

Table 9 shows the values of specific indirect effects obtained in the two studies.

Table 9. Mediation analysis.

Study 2					
Hypotheses	**Path**	**Standard Beta**	**t-Value**	***p*-Value**	**Decision**
H_{10}	ED→EI→SST	0.124	3.890	0.000	Supported
H_{11}	EP→EI→SST	0.128	3.741	0.000	Supported

In Model 2, educational intervention mediates economic development and sustainable space travel ($\beta_{ED\rightarrow EI\rightarrow SST}$ = 0.126, t = 3.890, $p < 0.001$). We calculated the mediation effect as follows: $0.2 < VAF_{ED\rightarrow EI\rightarrow SST} < 0.8$ ($VAF_{ED\rightarrow EI\rightarrow SST}$ = 0.395) [84]. Educational intervention plays a partial mediating role between economic development and space travel. Educational intervention mediates environmental protection and sustainable space travel ($\beta_{ED\rightarrow EP\rightarrow SST}$ = 0.128, t = 3.741, $p < 0.001$). Since the relationship between environmental protection and space travel is insignificant, educational intervention is fully mediated between environmental protection and space travel. The moderate f^2 of EI→SST also proves that educational intervention is important to sustainable space travel [83].

4.5. Discussion

Based on the duality theory, this study explores the relationship between two factors, economic development and environmental protection, as well as the relationship between space travel, environmental sustainability, and educational interventions, with the ultimate goal of achieving sustainable space travel. We also tried to identify the keys to help develop the concept of sustainable space travel.

In Model 1, H_1 and H_4 were supported, which means that residents recognize the benefits of the development of space travel for economic development and have sufficient concern for environmental sustainability, which is consistent with previous research [72]. H_2 and H_3 demonstrate the conflict between economic development and environmental protection in the traditional view. H_2 was supported, but the result of H_3 was not significant. The limitations of economic development on environmental sustainability have been widely mentioned in recent years, and many researchers have devoted themselves to solving their conflicting relationship [85]. Because space travel is small in scale, there is little direct evidence of its negative impact on the environment [86], which may be why H_3 was rejected. However, with the rapid development of the space travel industry, researchers' worries are not unnecessary. More than a hundred years ago, advanced scientists and critics believed that a real flying machine would be built a hundred years later, and two months after that, the Wright Brothers' flying machine took to the skies [87]. Predicting the future from the current perspective is difficult, and we need to approach the conflict between advanced technology and traditional perspectives with a developmental perspective. Researchers should make early assumptions and plan for potential problems regarding environmental impacts, resource use, and other directions.

In Model 2, four of the five hypotheses directly affecting the relationship were accepted (H_5–H_9, except H_6). The reason why the hypothesis test result of H_6 was not significant is similar to that of H_3. Space travel may be nascent, and people may not realize its environmental impact [88]. Residents have yet to think about its practical implications in the context of sustainable space travel. In verifying the intermediary relationship, both H_{10} and H_{11} were accepted. H_{10} demonstrates the partial mediating relationship between educational intervention and sustainable space travel. The causality between economic development and sustainable space travel is explained using sustainable education interventions. When people understand the economically sustainable perspective of sustainable space travel through education, they will recognize space travel even when the market is small and the cost is high [69]. In particular, H_{11} shows us the results of educational intervention as a complete mediating variable. Educational intervention is a way for residents who value environmental protection to re-understand space travel and it is an essential reason for the acceptance of sustainable space travel [89].

Sustainable space travel should be a fluid and evolving concept [52]. With only a small percentage of tourists being able to afford the high cost of travel, and most of these pioneers coming from the privileged class, the true understanding of space tourism will need to be refined through the development of society and by allowing more civilians to access space and make it a mass tourism activity. Therefore, until the concept is clearly defined, it is difficult to develop a specific educational approach to its implementation, but it is clear that education can intervene in the perception of sustainable space tourism.

At the end of the questionnaire, we asked Chinese residents about their views on space travel and sustainable space travel. Most residents showed a positive attitude toward the development of space travel (18 of 24) and expressed their thoughts to us. Some participants pointed to the need for environmental protection and sustainability and noted limitations on the population, including costs that only a wealthy few can afford, physical fitness considerations, and safety concerns.

> *Space-walk is still an activity for the rich, and those without money can only sleep-walk! However, we should adhere to the sustainable development strategy*. -LT from Sichuan Province

Some residents actively offered suggestions and were not shy about expressing their extraordinary expectations for this imaginary journey.

> *Space travel must be a development direction in the future and needs to be carried out step by step. It is hoped that the development of the space industry can be promoted by deepening cooperation between the government and enterprises*. -Boraemon from Jiangxi Province

Some residents also hold conservative views, raising questions about the potential dangers of space tourists and questioning the significance of space travel.

> *I think space travel should not be developed. Space is full of unknowns, and we should not explore it at will. It's also dangerous if someone with bad intentions goes into space and causes damage*. -Butterfly from Hebei Province

Interesting conflicting viewpoints from two previous studies express their own views on whether space travel can be a part of sustainable tourism. Spector et al. [90] presented an attractive viewpoint that space travel should be viewed across the traditional Earth-biological view of sustainability. Space travel could be an essential step in our journey to the depths of the universe in search of the future of humankind. Another is countered by Peeters [34], who argues that narrating space travel is a way to save humanity's future. Cosmic migration has become realistic with advanced technology that is an alternative to protecting the Earth to survive human beings.

5. Conclusions, Limitations, and Suggestions

5.1. Conclusions

This study explores the dual factors of economic development and environmental protection, based on the duality theory in the social context, and the relationship between space travel, environmental sustainability, and educational interventions, with the ultimate goal of achieving sustainable space travel. We believe the key to sustainable space travel is the binary coherence of economic and ecological sustainability factors that lie in educational interventions. Education can transform the dual factors from binary opposition to coherent sustainability. It also applies to the space travel industry toward sustainability.

The models demonstrate the conflict and convergence of perspectives. We attempted to use such contrasts to highlight the importance of educational interventions, which attained the aims of our study. From the traditional viewpoint, economic development and environmental protection viewpoints lead to conflicts between the development of the space travel industry and sustainability [91]. However, educational intervention makes the dual factors coherent to facilitate sustainable space travel [88]. The educational intervention serves as an essential mediator to allow space travel to demonstrate its ability to be both economically and environmentally sustainable by mapping out a sustainable path for space travel over a longer time. In addition, researchers have expressed their views on the sustainable aspects of space travel [52,69,72,88]. Collins and Autino [31] affirmed the rationality and feasibility of sustainable space travel in terms of economic growth, education, culture, and world peace.

Virgin Galactic's suborbital space trips cause 27 tons of carbon emissions in one trip. A transatlantic intercontinental flight emits 1.6 tons of carbon. A SpaceX orbital space trip is equivalent to 395 times the carbon emissions of an intercontinental flight. Rocket fuel is mainly composed of methane, kerosene, and liquid hydrogen, with kerosene being the most widely used because of its early use and mature technology [92]. The fuel for airplanes is mainly aviation kerosene, but because of the different supply chains, the species composition is also different, and the increase in rocket launches in a short period of time will not affect the supply of aviation fuel. With the progress of all aspects of technology, rockets will increasingly use liquid oxygen methane because of its simple acquisition and cheap production costs.

The recent Cop28 conference agreed on an energy transition away from fossil fuels [93]. With the development of technology, liquid oxygen and liquid hydrogen fuels, which have the best performance, will be widely used to reduce the use of fossil fuels. On the other hand, the conference also proposed a "Climate-related Loss and Damage Fund" for developing countries to compensate for climate losses in countries that are lagging, and several countries have pledged to contribute to this fund. The organization of the General Assembly proposed that there is a current need to provide USD 100 billion per year as a first step to compensate for the current situation, but for various reasons, it has not been carried out. By 2050, this figure could be USD 1.5 trillion, which is clearly unrealistic. Although the Cop document belongs to the international legal force globally, the General Assembly said that each country should develop its own environmental program according to its own situation. Decisions by national environmental agencies are important. The United States, China, Russia, and the European Union, as well as other relevant government agencies, should provide early scientific guidance and legal policies to ensure that the sustainable development of commercial space is monitored and implemented, and that relevant experience is accumulated.

Specifically, we have the following recommendations for achieving sustainability in space travel. In terms of environmental sustainability, we should first rely on the use of mandatory measures. The government should establish a law requiring space companies to pay a carbon tax when carrying out space travel, which is to be used for (a) neutralizing carbon dioxide emissions, (b) absorbing the cost of toxic substances, and (c) recycling and inputting space debris. Space tourists can also be required to pay carbon emission consumption tax to bear a certain responsibility for space travel, like the tax on common commodities in the USA and Japan. The government of the space travel operation activities can then manage taxation's revenue for programs to compensate the negative impact of emissions on the world. We also suggest that corporations refer to this portion of the contribution to reduce space travel queue times for tourists who actively practice low-carbon living. It has also been suggested that virtual space travel could be considered an alternative [72]. However, this experience may instead increase the demand for real space travel. And the overview effect evoked in the experience of space travel may positively impact tourists practicing sustainability and protecting planet Earth [94].

In terms of economic sustainability, we refer to Peeters' [54] view of space travel as a mode of transportation and the fact that after passing the nascent stage of the industry, when enthusiasts were driven by increasing personal fortunes, space travel's huge demand and high price premiums; then the economic sustainability can be attained. We believe that space travel needs more competitors to maintain a healthy supply market and accelerate growth. Legal and regulatory safeguards are also essential in this regard [95]. Researchers should also consider how to make space travel attractive and how to design services to make it more appealing. The attractiveness of space travel can be ensured through the design of suborbital and orbital travel novelty experiences, including marriage, photography, unique food and drink, sports, and funeral services.

Educational interventions played an essential role in the research model. China has permanently attached great importance to education on environmental protection and sustainable development [96]. The new generation of Chinese residents has made environmental protection an essential code of conduct [97]. Education is a crucial mediator in resolving the conflict between economic development and ecological protection, coherently connecting these two factors toward sustainable space travel.

The operationalization of educational interventions for sustainable space travel should start from the very beginning of compulsory education [98]. Education should be used as a foundation for sustainability by using simple, sustainable behaviors from life as demonstrations to help students understand. Education for sustainable space travel can be supplemented to enhance interest in learning. Sustainable teaching requires demonstrating the current state of the planet's energy resources. Sustainable space travel education should also illustrate the space industry's necessity, advancement, and irreplaceability regarding resources and energy access. Different sustainable education materials and concepts should be developed based on the local education level. We also found in the recovered responses that there is a difference in the understanding of space travel among respondents from different regions, regardless of whether they recognize the sustainability of space travel or not [99]. Sustainable education should be localized and practical. The forms of space travel education can be varied, and education on sustainable themes in space museums or science centers has proven to be very effective [100]. Theme-based lectures and community outreach are also good, as the content of space travel is always appealing.

This study also investigated residents' views on space travel within the context of China's oriental culture. Previous research on space travel has lacked the views of mainland Chinese residents [40]. In the results, we see that Chinese residents have a strong desire for space travel, and their thoughts on the significance of space travel itself, as well as concerns about price, safety, and pre-training, are prevalent. At the same time, it is common for residents to point fingers at space tourists concerning equality in terms of wealth and social status. Like Western respondents, residents' aspirations and concerns about space travel were common [101].

5.2. Limitations

Chang [102] investigated the attitudes of Taiwanese residents toward space travel without the mainland China samples, which caused the sample bias issue. In this study, there were no significant differences in the distribution of resident attributes. However, the samples for this survey were limited in size (284) and showed highly educated, youthful characteristics. The college-educated group accounted for 72.9%, and the 18–24-year-old group accounted for 59.9% of the total sample size. All regions of China should be covered as well. This study can improve the representation of the overall attitudes of Chinese population groups. Random sampling methods and more samples can be of help in the generalizability of this study. Future research could increase stratified random samples in the age and region distributions.

The sustainable view of space travel in this study is limited by the traditional perspective and is developed based on the sustainable dimension of conventional tourism. Space travel significantly differs from terrestrial tourism [26]. We want to establish a sustainable view of space travel. Suppose we only constrain our cognition to terrestrial tourism. In that case, the sustainable perspective will struggle to encompass sustainable space travel, which is the difficulty we encountered when conducting the literature review. As Chang [103] pointed out, space travel renews the boundaries of human activities, and the limits defined by the traditional concept of sustainability should also expand to space.

5.3. Suggestions for Future Research

The sustainability of space travel requires a practical basis and policy in all relevant industry chains [104], as well as an effective long-term export of pertinent information and ideas to the population. This study also demonstrates the attitudes of residents of China, the largest developing country, toward sustainable space travel. As sustainable development is the key to humanity's sustainability, we hope that it can be more firmly integrated with education so that we can implicitly make people cautious about space travel and all kinds of new products and technologies by systematically and scientifically critiquing the various perspectives of sustainability. Sustainability starts from the understanding of global citizens; thus, we explore how the sustainability of space travel can be realized, and we and our generations will have opportunities to experience space travel with its significance for human development [105]. With the vast differences between space travel and the traditional terrestrial realm objectively presented, it is time to develop the overwhelming perspectives on sustainable space travel. Researchers have begun to set their sights on the cosmos, and interdisciplinary research on our "relationship" with space is needed to allow humans to delve into space with curiosity and hope for the future.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Space travel records (without agents).

Year	Operator	Flight Type	Name	Price (USD/Million)	Flight Altitude/Destination	Note
2001	Roskosmos (Russian Federal Space Agency)	Soyuz TMA-32	Dennis Tito (USA)	20	International Space Station	The first space tourist.
2002	Roskosmos	Soyuz TMA-34	Mark Shuttle Worth (South African and UK)	20	International Space Station	
2005	Roskosmos	Soyuz TMA-7	Greg Olsen (USA)	19	International Space Station	
2006	Roskosmos	Soyuz TMA-9	Anousheh Ansari (USA, Female)	20	International Space Station	First female space tourist.
2007	Roskosmos	Soyuz TMA-10	Charles Simonyi (USA)	25	International Space Station	
2008	Roskosmos	Soyuz TMA-13	Richard Garriott (USA)	30	International Space Station	
2009	Roskosmos	Soyuz TMA-14	Charles Simonyi (USA)	35	International Space Station	This tourist has traveled to space twice.
2009	Roskosmos	Soyuz TMA-16	Guy Laliberte (Canada)	35	International Space Station	
2021	Space X	Falcon 9 rocket and Dragon	Jared Isaacman (USA) Hayley Arceneaux (USA, Female) Chris Sembroski (USA) Sian Proctor (USA)	35	575 km	SpaceX's first purely commercial manned mission (the first to send four ordinary people into space).
2021	Roskosmos	Soyuz MS-20	Yusaku aezawa (Japan) Yozo Hirano (Japan) Alexander Misurkin	--	International Space Station	Prices are not disclosed.
2021	Virgin Galactic	White Knight 2	Richard Branson (UK) Beth Moses (USA, Female) Colin Bennett (USA) Sirisha Bandla (USA, Female)	Free	89.2 km	Richard Branson is the founder of the Virgin Group (so this trip was free).
2021	Blue Origin	New Shepard	Jeff Bezos (USA) Mark Bezos (USA) Wally Funk (USA, Female) Oliver Daemen (The Nederlands)	Free	107 km	Jeff Bezos founded the Blue Origin (so this trip was free). Oliver Daemen was named the youngest space traveler.
2021	Blue Origin	New Shepard NS-18	William Shatner (Canada) Audrey Powers (USA, Female) Chris Boshuizen (Australia) Glen de Vries (USA)	--	107 km	Prices are not publicized.

Table A1. *Cont.*

Year	Operator	Flight Type	Name	Price (USD/Million)	Flight Altitude/Destination	Note
2021	Blue Origin	New Shepard Ns-19	Michael Anthony Strahan (USA) Dylan Taylor (USA) Lane Bess and his son Cameron (USA) Laura Shepard Churchley (Female) Evan Dick (USA)	--	108 km	Prices are not publicized.
2022	SpaceX	Falcon 9 rocket and Dragon	Michael López-Alegría (USA) Larry Connor (USA) Mark Pathy (Canada) Eytan Stibbe (Israel)	55	International Space Station	
2022	Blue Origin	New Shepard Ns-20	Sharon Hagle (USA) Marc Hagle (Female) Gary Lai (USA) Marty Allen (USA) Jim Kitchen (USA) George Nield (USA)	--	100 km	Prices are not publicized.
2022	Blue Origin	New Shepard NS-21	Evan Dick (USA) Katya Echazarreta (Mexico, Female) Hamish Harding (UK) Victor Correa Hespanha (Brazil) Jaison Robinson (USA) Victor Vescovo (USA)	--	106 km	Prices are not publicized.
2023	Virgin Galactic	VSS Unity	Walter Villadei (Italy) Pantaleone Carlucci (Italy) Lt.Col.Angelo Landolfi (Italy) Colin Bennett (USA)	25	85 km	
2023	Virgin Galactic	VSS Unity	Jon Goodwin (UK, Female) Keisha Schahaff (Antigua and Barbuda, Female) Anastatia Mayers (Antigua and Barbuda, Female)	25	85 km	

Appendix B

Below is the history of some of the developing space travel companies, which show the rapid progression of the development of space travel in the United States and China in relevant aspects.

Table A2. SpaceX.

SpaceX (USA)	
Time	**Milestone**
2002	SpaceX was founded in 2002.
2006	The company was awarded a contract by NASA for commercial orbital transportation services.
2008	The company announced it won a USD 1.6 billion contract from NASA for commercial resupply services.
2012	The company took on its first official cargo mission to the International Space Station, launching a Falcon 9 rocket that lifted the Dragon capsule into orbit, where it spent 18 days.
2013	In October, the first reusable rocket, "Grasshopper", was manufactured.
2014	In May, the reusable rocket, Falcon9, landed safely after a test flight, reaching a peak of 1 km in the air. In September, Boeing and SpaceX won NASA's USD 6.8 billion "space taxi" contract to carry astronauts to the International Space Station over the next few years.

Table A2. *Cont.*

SpaceX (USA)	
Time	**Milestone**
2015	In November, the company received an order for a "space taxi" from NASA. In December, the Falcon9 rocket was successfully launched, and the first stage of the rocket was successfully recovered.
2017	In June, the first stage of the Falcon9 rocket landed on a floating platform in the Pacific Ocean as planned and was successfully recovered at sea.
2018	A total of 11 reused rockets were successfully launched.
2020	In February, plans for private space tourism were announced, with each ship carrying four tourists.

Table A3. Virgin Galactic.

Virgin Galactic (UK)	
Time	**Milestone**
2004	Virgin Galactic was founded in 2004. In March of the same year, the USA House of Representatives passed legislation to promote the development of a new commercial human space industry.
2013	The SS2 (SpaceShipTwo) aircraft, developed by the company, conducted its first and second powered test flights on April 29 and September 5, respectively.
2014	In October, one of Virgin Galactic's planes, SpaceShipTwo, crashed in California's Mojave Desert.
2016	In February, the company unveiled a new version of its spacecraft for future space travel. In September, the spacecraft "VSS Unity" completed its maiden flight.
2021	In May, the company successfully tested its first manned rocket flight and was certified to operate commercial space travel that year.

Table A4. Blue Origin.

Blue Origin (USA)	
Time	**Milestone**
2000	Blue Origin was founded in 2000.
2015	In November, the company launched its New Shepard rocket to an altitude of 100 km and successfully recovered it.
2016	In December, the New Shepard rocket completed its seventh launch and landed successfully. The unmanned Capsule Crew Capsule 2.0 was successfully deployed during this period.
2018	In April, the company again successfully launched and recovered its New Shepard suborbital vehicle.
2021	Blue Origin's first manned flight was successful.

Table A5. Beijing Interstellar Glory Space Technology Co. (iSpace).

Beijing Interstellar Glory Space Technology Co. (iSpace) (China)	
Time	**Milestone**
2016	iSpace was founded in October 2016.
2018	In April, iSpace's first solid demonstration rocket, Hyperbola-1S, was launched in Hainan Province. This was China's first truly private rocket, and the first private rocket outside the United States to achieve flight success.
2019	In July, iSpace made history with the successful launch of its Hyperbola-1y1 remote carrier rocket from the Jiuquan Satellite launch center in Northwest China, becoming the first private company in China to successfully complete the launch mission of the carrier rocket into orbit, achieving a breakthrough in the successful launch of China's private carrier rocket.
2023	In November, iSpace's Hyperbola-2 demonstration rocket mission was a complete success. In December, iSpace's Hyperbola-2 rocket flight mission was a complete success, and Chinese commercial aviation has made a great breakthrough in the reusable technology of liquid launch vehicles.

Table A6. Glavkosmos.

Glavkosmos (Russia)	
Time	**Milestone**
1985	Glavkosmos of the USS was founded in 1985
2012	Glavkosmos became the main contract integrator for Russian space companies involved in the Russian-European program "Soyuz at the Guiana Space Center".
2014	First launch of the Soyuz-2 launch vehicle with six satellites (the USA, the UK, Norway, and Russia) as a secondary payload.
2016	Glavkosmos became an official distributor of the Earth observation data from the Resurs-P and Kanopus-V satellite constellations. In the same year, Glavkosmos became the main subcontractor to provide the launch services for OneWeb program.
2017	Glavkosmos became the operator of the commercial Soyuz-2 launches from the spaceports of Vostochny, Baikonur and Plesetsk.
2019	Glavkosmos started implementing the launch program for OneWeb satellites. The first six satellites were injected into target orbits.
2021	The State Space Corporation Roscosmos authorized Glavkosmos to search for "space tourists"—commercial non-professional space flight participants. The same year, Glavkosmos became a co-organizer of the International Space Exploration Conference (Global Space Exploration Conference—GLEX-2021) in St. Petersburg.
2022	Glavkosmos started offering Russian launch vehicles for dedicated space missions. The relevant transport equipment includes the Soyuz 2.1a launch vehicle and the Soyuz MS spacecraft.
2023	Glavkosmos organized the launch of 42 small spacecraft from Vostochny; for the cosmodrome, the launch set a record for the number of simultaneously launched Russian satellites.

Appendix C

There are three main effective programs for space debris removal: laser removal, satellite removal, and combined programs.

Table A7. Space debris removal programs.

Country	Measures
China	In 2016, they launched the self-developed "Invitation Dragon 1" space debris remover, which uses an outstretched mechanical arm to capture space debris and change its original orbit.
UK	The Sally Space Center of the United Kingdom, funded by the European Union's Seventh Framework Program (F7) in cooperation with European research institutions, launched the "Remove DEBRIS" project in 2013. The project realized on-orbit validation tests of flynet capture, visual navigation of space targets, harpoon capture, and towed sail de-orbit. Its "space harpoon" can smash larger space garbage, and the broken garbage will be incinerated by itself after entering the atmosphere through a garbage collection net and deorbiting device.
The USA	(a) NASA launched the "Orion" program in 1993 to remove debris from near-Earth orbit using ground-based pulsed lasers. ORION shifted its focus from ground-based lasers to space-based lasers in 2014, using smaller optics and lasers for space debris processing in geosynchronous orbit (GEO). (b) The USA Air Force's Space Fence program was launched, which uses radar to track space junk. Lockheed Martin, the USA military giant, contracted with EOS, an Australian optronics company, to collaborate on the use of light cavity and laser technology to search for, track, and identify space debris.

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