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High School Student’s Interest in Particle Physics

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1. Necessity of the Study

1. Advancement and Impact of Particle Physics

- Particle physics explores the fundamental particles and their interactions that constitute nature, based on quantum mechanics and the theory of relativity.
- Its technologies have been applied to medical imaging (PET, MRI), radiation therapy, semiconductors, the internet (WWW), and precision sensors, significantly influencing both daily life and industry.
- It is not only a theoretical science but also a key driver of technological and societal advancement.
- These scientific outcomes are closely linked to our everyday lives. *(Sarah, 2022; Anja, 2022; Hasnain, 2021)*

2. Increasing Importance of Quantum Physics Education

- Since the 2000s, the importance of quantum physics education has been emphasized.
- Technologies such as smartphones, semiconductors, and medical devices are based on quantum mechanics, so understanding quantum mechanics is important. *(Im Sungmin, 2022)*

3. High School Students' Perceptions and Interest in Particle Physics

- Helping students recognize the connection between particle physics and everyday life is a key goal of science education.
- For students who choose science tracks, it offers opportunities for career exploration and academic growth.
- This study investigates students' interest in particle physics and how they perceive its relevance to their daily experiences.

1-1. Research Questions

1. What is the level of high school students' interest in particle physics?

2. How does the level of interest in particle physics differ depending on students' subject choices for the College Scholastic Ability Test (CSAT)—social studies or science?

3. What effect does participation in a basic nuclear physics education program have on the perceptions of science high school students?

2. Research Method

1) Research Subjects

303 students from general high schools

2) Survey Method and Period

- online survey
- IPPI questionnaire(5-point Likert scale)

3) Research Procedures and Tools

- Reliability analysis (internal consistency)
- Interest distribution: frequency analysis, descriptive statistics
- Comparison by elective subjects: independent samples t-test
- Tool: IBM SPSS Statistics

2. Research Method

No	Item Category	Context	Task	Exemplar item
01	Learning more about the functional principle of technical devices	Understanding technical devices in everyday life	Receiving information (observing, reading, and listening)	Learning more about the functional principle of devices that detect particles (e.g. digital camera)
02	Learning more about natural phenomena	Enrichment of emotional experiences		Learning more about how particle physics helps understand the orthern lights
03	Learning more about the relevance of physics for society	Relevance for society		Learning more about how a particle accelerator contributes to the peaceful collaboration of diverse nations
04	Learning more about qualitative physics	Science I (qualitative)		Learning more about which interaction binds the elementary particles in the nucleus space together
05	Learning more about quantitative physics	Science II (quantitative)		Learning more about how many elementary particles constitute an object, such as a pen
06	Getting insight into technical jobs	Vocation I (technical,scientific)		Getting insight into how particle accelerators are used in the electronics industry
07	Getting insight into jobs related to humans	Vocation II (medical,artistic, and counselling)		Getting insight into the work flow in a medical diagnostic centre
08	Constructing technical devices	Enrichment of emotional experiences	Hands-on (constructing objects, conducting experiments)	Building a particle detector out of everyday objects
09	Planning experiments	Science I (qualitative)	Minds-on (devising and calculating)	Planning an experiment to explore the structure of an atom
10	Calculating physical quantities	Science II (quantitative)		Calculating the energy when two particles moving with nearly the speed of light collide
11	Discussing the societal relevance of physics	Relevance for society	Evaluation and discussion	Discussing why research in particle physics is important for society

01	011	Particle accelerator
	012	Devices that detect particles (e.g. digital camera)
	013	Devices that accelerate particles (e.g. electron microscope)
02	021	Particle physics and the big bang
	022	Particle physics and the northern lights
	023	Cosmic particles
03	031	A particle accelerator and the peaceful collaboration of diverse nations
	032	Particle detectors and smuggled arms
	033	Particle physics and art authentication
04	041	Particles and interactions
	042	Particles in the nucleus space of an atom
	043	The interaction binding together the nucleus space of an atom
05	051	Particles of objects (e.g. pen) (quantitative)
	052	Acceleration of particles (quantitative)
	053	Masses of particles (quantitative)
06	061	Occupational groups contributing to particle physics
	062	Jobs outside science for particle physicists
	063	Particle accelerators in the electronics industry
07	071	Medical diagnostics
	072	Particle accelerators to cure diseases
	073	Particle accelerators for studying volcanoes or pyramids
08	081	Build a particle detector out of daily life objects (hands-on)
	082	Build an electromagnet to influence the direction of a particle (hands-on)
	083	Transform a mobile phone into a particle detector (hands-on)
09	091	Plan an experiment for particle acceleration (minds-on)
	092	Plan an experiment to study the structure of an atom (minds-on)
	093	Plan an experiment to influence the direction of a particle (minds-on)
10	101	Calculate the energy of a particle collision at the speed of light (minds-on)
	102	Calculate number of particles in human hair (minds-on)
	103	Calculate the mass of particles (minds-on)
11	111	Particle physics has changed our daily life (discussion)
	112	The societal relevance of particle physics (discussion)
	113	EU investments in particle detectors (discussion)

Sarah , Martin, Julia & Sascha(2022). Students' interest in particle physics: conceptualisation, instrument development, and evaluation using Rasch theory and analysis, International Journal of Science Education, 44(15), 2353-2380.

3. Results

1) Reliability analysis

- Internal consistency of the Category (Cronbach's alpha): .994

	Category	Cronbach's alpha
01	Learning more about the functional principle of technical devices	0.976
02	Learning more about natural phenomena	0.974
03	Learning more about the relevance of physics for society	0.967
04	Learning more about qualitative physics	0.983
05	Learning more about quantitative physics	0.974
06	Getting insight into technical jobs	0.976
07	Getting insight into jobs related to humans	0.967
08	Constructing technical devices (hands-on)	0.971
09	Planning experiments (minds-on)	0.982
10	Calculating physical quantities (minds-on)	0.973
11	Discussing the societal relevance of physics(discussion)	0.976

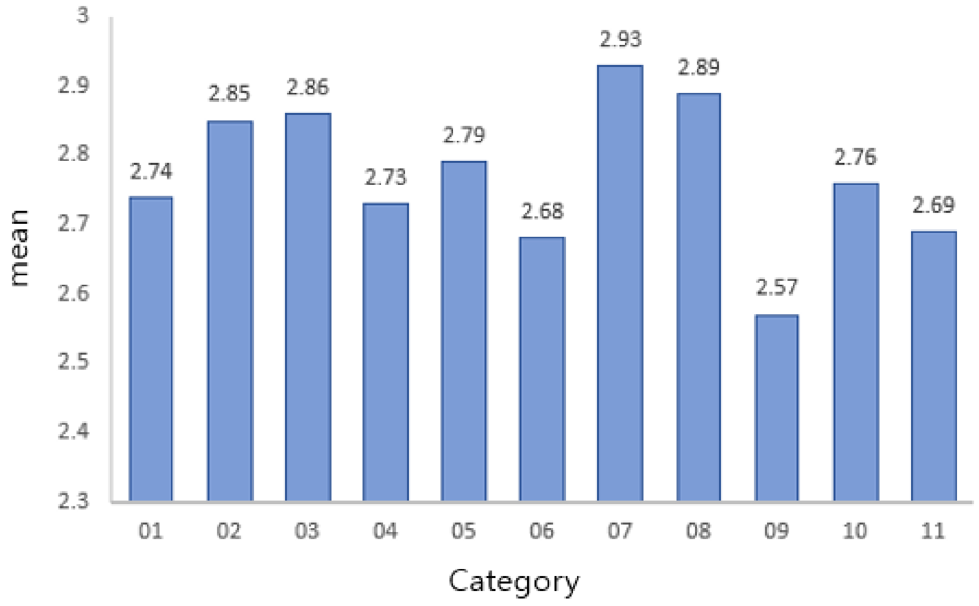
2) Frequency analysis

Participants	Grade			Gender		Inquiry	
	First	Second	Third	Male	Female	Science	Social Studies
303 (100%)	121 (39.9%)	84 (27.7%)	98 (32.3%)	145 (47.9%)	158 (52.1%)	202 (66.7%)	101 (33.3%)

< 1. Distribution of high school students' interest in particle physics >

	mean	s.d
Interest in particles	2.77	1.16

	Category	mean	s.d
01	Learning more about the functional principle of technical devices	2.74	1.27
02	Learning more about natural phenomena	2.85	1.25
03	Learning more about the relevance of physics for society	2.86	1.24
04	Learning more about qualitative physics	2.73	1.29
05	Learning more about quantitative physics	2.79	1.26
06	Getting insight into technical jobs	2.68	1.24
07	Getting insight into jobs related to humans	2.93	1.28
08	Constructing technical devices (hands-on)	2.89	1.29
09	Planning experiments (minds-on)	2.57	1.24
10	Calculating physical quantities (minds-on)	2.76	1.27
11	Discussing the societal relevance of physics(discussion)	2.69	1.29



- **Average interest level**: 2.77 (on a 5-point Likert scale)
- **High-interest items**
  - Insight into jobs related to humans (2.93)
  - Constructing technical devices (2.89)
  - Understanding the relevance of physics in society (2.86)
- **Low-interest items**
  - Planning experiments (2.57),
  - Insight into technical jobs (2.68)
  - Topics involving calculation or abstract concepts
- **Interpretation**

  → Students showed greater interest in topics **related to real-life and career relevance**, while showing **lower interest in abstract or calculation-based topics**.

3. Results

< 1. Distribution of high school students' interest in particle physics >

The overall average level of interest was moderate (2.77), but interest levels varied significantly depending on the item.

High-interest items (top-ranked)

- Strong interest in topics related to healthcare and everyday life:
  - Particle accelerators for disease treatment
  - Building a particle detector using a smartphone
  - Topics related to medical diagnosis, smuggling control, and the origin of the universe (Big Bang)

showed relatively high interest

- Some topics connected to social relevance also received high interest:
  - Art authentication, analysis of everyday objects, building detectors by hand

Low-interest items (bottom-ranked)

- Low interest in quantitative calculation and experimental design:
  - Calculating particle mass or number, planning experiments, conducting electromagnetic experiments
- Topics involving international cooperation and socio-political discussions also showed low interest:
  - Multinational collaboration, discussions on the societal meaning of particle physics, and political or civic contexts

Interpretation and Implications

→ Students showed higher interest in topics that are hands-on and closely related to real life, but lower interest in abstract, calculation-heavy, or socially/politically contextualized topics.

→ This suggests that **'personal relevance' plays a more important role than the topic itself** in shaping student interest.

	Item	mean	s.d
072	Particle accelerators to cure diseases	3.01	1.39
083	Transform a mobile phone into a particle detector (hands-on)	2.97	1.39
021	Particle physics and the big bang	2.96	1.35
023	Cosmic particles	2.95	1.37
032	Particle detectors and smuggled arms	2.94	1.37
033	Build a particle detector out of daily life objects (hands-on)	2.93	1.37
071	Medical diagnostics	2.93	1.36
081	Particle physics and art authentication	2.93	1.38
051	Particles of objects (e.g. pen) (quantitative)	2.89	1.34
052	Particle accelerators for studying volcanoes or pyramids	2.84	1.39
073	Acceleration of particles (quantitative)	2.84	1.36
012	Devices that detect particles (e.g. digital camera)	2.83	1.33
102	Calculate number of particles in human hair (minds-on)	2.81	1.37
062	Build an electromagnet to influence the direction of a particle (hands-on)	2.78	1.34
082	Jobs outside science for particle physicists	2.78	1.35
041	Calculate the energy of a particle collision at the speed of light (minds-on)	2.76	1.34
101	Particles and interactions	2.76	1.35
042	Particles in the nucleus space of an atom	2.75	1.35
013	EU investments in particle detectors (discussion)	2.73	1.34
113	Devices that accelerate particles (e.g. electron microscope)	2.73	1.35
031	A particle accelerator and the peaceful collaboration of diverse nations	2.7	1.28
103	Calculate the mass of particles (minds-on)	2.69	1.32
043	The interaction binding together the nucleus space of an atom	2.68	1.29
111	The societal relevance of particle physics (discussion)	2.67	1.34
112	Particle physics has changed our daily life (discussion)	2.67	1.34
011	Masses of particles (quantitative)	2.65	1.28
053	Particle accelerator	2.65	1.28
063	Particle accelerators in the electronics industry	2.63	1.28
022	Particle physics and the northern lights	2.62	1.26
061	Occupational groups contributing to particle physics	2.61	1.28
092	Plan an experiment to study the structure of an atom (minds-on)	2.59	1.29
093	Plan an experiment to influence the direction of a particle (minds-on)	2.56	1.29
091	Plan an experiment for particle acceleration (minds-on)	2.55	1.27

< 2. Differences in the distribution of high school students' interest in particle physics – by elective subject>

	Category	mean
07	Getting insight into jobs related to humans	3.31
08	Constructing technical devices (hands-on)	3.26
02	Learning more about natural phenomena	3.22
03	Learning more about the relevance of physics for society	3.18
05	Learning more about quantitative physics	3.15
10	Calculating physical quantities (minds-on)	3.14
01	Learning more about the functional principle of technical devices	3.12
04	Learning more about qualitative physics	3.11
06	Getting insight into technical jobs	3.02
11	Discussing the societal relevance of physics(discussion)	3.01
09	Planning experiments (minds-on)	2.95

<Science>

	Category	mean
03	Learning more about the relevance of physics for society	2.22
07	Getting insight into jobs related to humans	2.17
08	Constructing technical devices (hands-on)	2.16
02	Learning more about natural phenomena	2.10
05	Learning more about quantitative physics	2.08
11	Discussing the societal relevance of physics(discussion)	2.07
06	Getting insight into technical jobs	1.99
10	Calculating physical quantities (minds-on)	1.99
01	Learning more about the functional principle of technical devices	1.98
04	Learning more about qualitative physics	1.97
09	Planning experiments (minds-on)	1.81

<Social Studies>

1. Science vs. Social Studies Comparison

- Science group → Higher interest than social studies group across all categories

2. Commonalities

- Hands-on activities using familiar tools (e.g., smartphones, medical devices) → High interest in both groups
- Personally relevant topics → No major difference between groups

3. Differences

- **Science group**

– Preference for experiments, technology, and calculation

– Focus on scientific inquiry and real-world application

- **Social studies group**

– Overall lower interest

– Preference for explanation-based, everyday topics (e.g., diseases, smuggling)

– Experimental design items → Lower ranking

– Discussion-based items → Relatively higher ranking

3. Results

1. Overall Interest in Particle Physics among High School Students

- Average interest level: **moderate (2.77 out of 5, Likert scale)**
- **High interest**:
  Topics related to careers (e.g., disease treatment, medical diagnosis)
  Hands-on activities using everyday tools (e.g., turning a smartphone into a particle detector)
- **Low interest**: Experimental design, abstract concepts, quantitative calculation

- **Social Issues**
  - High interest in **real-life social examples** such as disease treatment, safety, smuggling control, and art authentication
  - In contrast, **lower interest** in topics related to international issues, global cooperation, or abstract social systems
  - Also low interest in **discussion-based items**, such as "the societal meaning of particle physics"

    → **Interest is shaped more by 'personal relevance' than by the topic itself**

2. Differences by Elective Subject

1) Commonalities

- Both groups showed high interest in **activities using familiar tools connected to everyday life**
- Ex: Building a particle detector from a smartphone, exploring how medical devices work

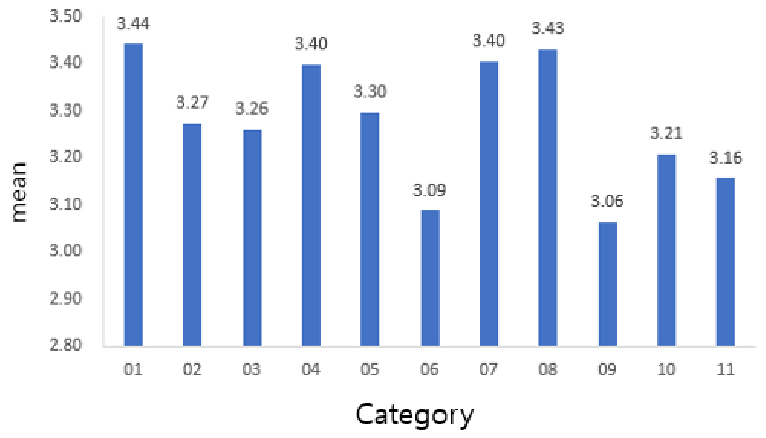
→ **No subject-based differences for personally relevant topics**

2) Differences

- **Science**
  - Generally showed **higher interest**
  - Actively engaged in activities related to **experiments, technology, and calculation**
  - Viewed particle physics as a topic for **scientific inquiry and application (** Strong interest in **experiment-driven topics)**
- **Social Studies**
  - Generally showed **lower interest**
  - Responded more to **explanation-based items** with clear connections to daily life
  - Ex: Disease treatment, smuggling control, hospital-related examples
  - Low interest in **experimental design, calculation, and discussion-focused topics**

< 3. Science High school students' interest in particle physics (N=117) >

	mean	s.d
Interest	3.18	0.989490



- **Interest Level**: Above average (3.18 out of 5, Likert scale)
- **High Interest**:
  - Understanding the operating principles of technical devices, and constructing experimental tools
  - Interest in careers related to people, and in qualitative and quantitative physics concepts
- **Low Interest**:
  - Planning experiments, understanding technical careers, discussing the social relevance of particle physics

Students showed steady interest not only in topics related to **everyday life**, but also in areas involving **technology, experimentation, and scientific calculation**.

	Item	mean	s.d
021	Particle physics and the big bang	3.60	1.273
083	Transform a mobile phone into a particle detector (hands-on)	3.59	1.219
052	Acceleration of particles (quantitative)	3.57	1.140
072	Particle accelerators to cure diseases	3.57	1.213
013	Devices that accelerate particles (e.g. electron microscope)	3.50	1.088
041	Particles and interactions	3.48	1.103
011	Particle accelerator	3.45	1.079
071	Medical diagnostics	3.45	1.221
042	Particles in the nucleus space of an atom	3.44	1.206
081	Build a particle detector out of daily life objects (hands-on)	3.43	1.241
033	Particle physics and art authentication	3.42	1.212
032	Particle detectors and smuggled arms	3.38	1.238
012	Devices that detect particles (e.g. digital camera)	3.38	1.081
023	Cosmic particles	3.35	1.147
101	Calculate the energy of a particle collision at the speed of light (minds-on)	3.31	1.102
051	Particles of objects (e.g. pen) (quantitative)	3.29	1.107
043	The interaction binding together the nucleus space of an atom	3.28	1.202
082	Build an electromagnet to influence the direction of a particle (hands-on)	3.27	1.222
102	Calculate number of particles in human hair (minds-on)	3.22	1.084
062	Jobs outside science for particle physicists	3.21	1.121
111	Particle physics has changed our daily life (discussion)	3.20	1.147
063	Particle accelerators in the electronics industry	3.20	1.085
073	Particle accelerators for studying volcanoes or pyramids	3.19	1.144
113	EU investments in particle detectors (discussion)	3.18	1.096
092	Plan an experiment to study the structure of an atom (minds-on)	3.10	1.199
103	Calculate the mass of particles (minds-on)	3.09	1.129
112	The societal relevance of particle physics (discussion)	3.09	1.122
091	Plan an experiment for particle acceleration (minds-on)	3.06	1.154
053	Masses of particles (quantitative)	3.03	1.102
093	Plan an experiment to influence the direction of a particle (minds-on)	3.03	1.125
031	A particle accelerator and the peaceful collaboration of diverse nations	2.97	1.200
022	Particle physics and the northern lights	2.87	1.118
061	Occupational groups contributing to particle physics	2.85	1.061

< Introductory Program in Nuclear Physics Education (with RAON) : Science High School >

1. Program Title: Introductory Nuclear Physics Program for Future Researchers
2. Participants: High school students or above interested in nuclear physics
3. Curriculum: Online lectures and on-site training in basic nuclear physics and experimental data analysis

< Online (ZOOM) and On-site Lectures > (5 sessions × 2 hours = 10 hours total)

1. The Big Bang and the Origin of Cosmic Elements
2. Nuclear Structure and Nuclear Force
3. RAON Nuclear Physics: Oppenheimer or Iron Man?
4. Overview of Particle Accelerators

< Field Practical Training (Research Institute Visit) >

1. Day 1: Introduction to Heavy Ion Accelerators
    - Practical Training 1: Isotope Production Simulation using LISE++
    - Practical Training 2: KoBRA Data Analysis – Gamma Spectrum, Half-life Calculation
2. Day 2
    - Facility Introduction: Rare Isotope Production and Measurement (ISOL, IF Devices)
    - Field Tour: ISOL and IF Experimental Laboratories

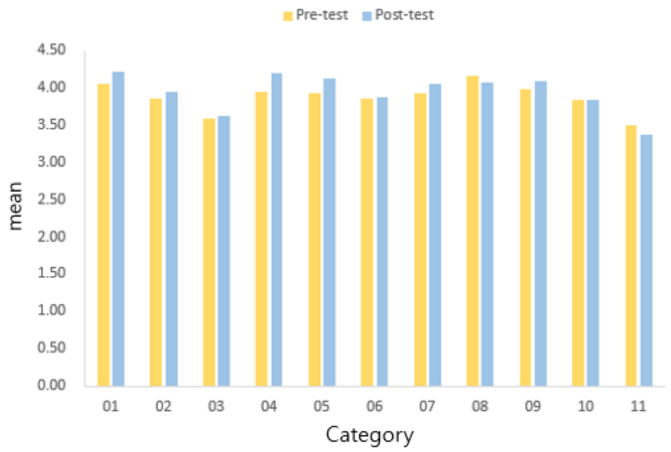
- Introductory nuclear physics education program jointly operated by RAON and Jeonbuk Science High School
- Volunteer participants from Jeonbuk Science High School
- Analysis of participant changes based on pre- and post-program surveys (16 out of - 21 participants completed both surveys)

3. Results

< 3-1. Introductory Program in Nuclear Physics Education (with RAON) : Science High School (N=16)>

Pre-test		Post-test	
mean	s.d	mean	s.d
3.87	0.53	3.99	0.58

	Item	Pre-test		Post-test	
		mean	s.d	mean	s.d
011	Particle accelerator	4.14	0.535	4.29	0.611
012	Devices that detect particles (e.g. digital camera)	3.93	0.997	4.00	0.784
013	Devices that accelerate particles (e.g. electron microscope)	4.07	0.917	4.36	0.745
021	Particle physics and the big bang	3.93	0.997	4.07	1.141
022	Particle physics and the northern lights	3.79	1.369	3.79	1.251
023	Cosmic particles	3.86	1.231	4.00	1.177
031	A particle accelerator and the peaceful collaboration of diverse nations	3.07	1.269	2.79	1.188
032	Particle detectors and smuggled arms	3.86	1.231	3.93	0.997
033	Particle physics and art authentication	3.86	1.027	4.14	0.663
041	Particles and interactions	4.14	1.027	4.36	0.929
042	Particles in the nucleus space of an atom	3.86	1.099	4.14	1.099
043	The interaction binding together the nucleus space of an atom	3.86	1.231	4.07	1.141
051	Particles of objects (e.g. pen) (quantitative)	3.93	1.141	4.14	1.027
052	Acceleration of particles (quantitative)	4.07	0.917	4.29	0.726
053	Masses of particles (quantitative)	3.79	0.975	3.93	1.072
061	Occupational groups contributing to particle physics	3.86	1.231	3.43	1.158
062	Jobs outside science for particle physicists	4.00	1.109	4.29	0.825
063	Particle accelerators in the electronics industry	3.71	0.994	3.93	0.917
071	Medical diagnostics	4.00	0.961	4.07	0.917
072	Particle accelerators to cure diseases	4.14	0.949	4.14	0.864
073	Particle accelerators for studying volcanoes or pyramids	3.64	1.151	3.93	0.917
081	Build a particle detector out of daily life objects (hands-on)	4.14	1.231	4.14	1.167
082	Build an electromagnet to influence the direction of a particle (hands-on)	4.14	1.027	3.86	1.027
083	Transform a mobile phone into a particle detector (hands-on)	4.21	1.122	4.21	0.802
091	Plan an experiment for particle acceleration (minds-on)	4.07	0.917	4.07	0.917
092	Plan an experiment to study the structure of an atom (minds-on)	4.00	0.961	4.14	0.864
093	Plan an experiment to influence the direction of a particle (minds-on)	3.86	1.099	4.07	1.141
101	Calculate the energy of a particle collision at the speed of light (minds-on)	3.79	1.122	4.21	1.051
102	Calculate number of particles in human hair (minds-on)	3.86	0.949	4.36	0.633
103	Calculate the mass of particles (minds-on)	3.86	0.864	4.21	0.975
111	Particle physics has changed our daily life (discussion)	3.50	1.092	3.36	1.151
112	The societal relevance of particle physics (discussion)	3.36	1.008	3.43	1.342
113	EU investments in particle detectors (discussion)	3.64	1.008	3.36	1.082



- **Overall interest increased slightly**, from 3.87 (pre-test) to 3.99 (post-test).
  Students already had high interest in particle physics, and the program helped maintain or slightly boost that interest.
- **Interest was maintained or improved** in items related to:
  - **Careers and hands-on activities**, such as particle accelerators, medical diagnostics, and using digital tools like smartphones
  - **Conceptual understanding and quantitative topics**, including particle interactions and acceleration
- **Interest decreased** in:
  - **Social and political topics**, such as international cooperation or discussions on the societal meaning of particle physics
  - **Occupational themes** not directly tied to students' personal goals
- **Implications**:
  The program was effective in sustaining interest where students could see **practical applications and personal relevance**.
  However, **abstract, societal, or discussion-based topics** remained less engaging, suggesting the importance of connecting content to students' everyday lives and future careers.

3. Results

1. Pre-Post Average Interest Level: Pre 3.87 → Post 3.99

- Participating students already had high interest in nuclear/particle physics, and their level of interest remained stable even after the program.
- Changes in interest showed varied responses depending on the content and context of each item.

2. Analysis of Interest Changes by Major Item

- **Maintained and Improved:** Concept understanding, hands-on experiment activities, technology application, and job-related items.
- **Decreased:** Discussions on the relevance of physics and society, international cooperation (multinational accelerators), and discussion topics on socio-political relevance

3. Post-Program Survey

1) Changes in Understanding of Nuclear and Particle Physics

- Students specifically mentioned practical application areas such as "medical treatment, diagnosis, robotics, and rare isotopes."
- They demonstrated a deeper understanding of concepts beyond simple definitions, specifically mentioning concepts like "fermion structure," "elementary particles," and "heavy ion accelerators."
    - "It was good to learn more about the structure of fermions."
    - "I used to think of accelerators as simple devices, but I realized they are used in multiple scientific applications."

2) Changes in Perception of Accelerator Experiments

- Accelerators were perceived as moving from simple physical devices to tools connected to complex and diverse fields.
- Specifically mentioned applications in life sciences, rare element detection, and medical diagnosis.
    - "I didn't know it was used so much in life sciences."

3) Changes in Career-Related Perception

- Some students specifically set career directions such as "nuclear physicist," "semiconductor specialist," or "medical device developer."
- Students recognized the relevance between their career paths and the field of physics (including both direct and indirect connections).
    - "I was able to have greater interest in the field of physics, including nuclear physics."
    - "I thought I wanted to become someone who creates medical devices or software."

4. Conclusion

1. Designing Career-Linked Topics (General Recommendation)

- Connect nuclear and particle physics with actual career fields, including medicine, semiconductors, and diagnostic technologies.

2. Strengthening Concrete Experience-Based Teaching and Learning Methods

- Provide hands-on activities using familiar tools and materials, such as simple experiments and model construction.

3. Relationship between Nuclear & Particle Physics and Society

- Incorporate discussion activities to help students understand the social implications and relevance of nuclear and particle physics.

4. Activating Collaborative Programs with Research Institutes

- Offer opportunities for in-depth learning in relation to career development.
- Facilitate program connections with active research sites, such as RAON.

Thank you.