| **OrientationCompass with solid fill** | **QR audio** |
| --- | --- |

Through the preceding activities some questions arose about the Museum's glass vase....

1. What was the (social) position of the craftsmen in Byzantium? Can we investigate the components of the glass used in the 4th century AD?

2. Have these products been exported and to where? Can we find similar products in Portugal, Cyprus or elsewhere?

3. Can we compare it with a glass product manufactured today? Are there any similarities/differences?

4. Can we make assumptions about the use of these glass products? What tests can we perform?

*Discuss the above questions as a whole class*

**How can we answer these questions?**

**Record the results of the discussion**

| ***The students record the results of the discussion, concluding with the following:***  **To answer the above questions we need to:**   * **Enlarge the object to see details** * **Identify the ingredients from which it is made** * **Detect components from any residues inside the glass jar** * **Identify ingredients that are an indication of preservation** |
| --- |

| *Record the opinions discussed*  *with a short video or sound recording.*  *Call it “1.a Problem and Solutions”* | *QR audio* |
| --- | --- |

| **Conceptualization Questions outline** | **QR audio** |
| --- | --- |

*Discuss as a whole class.*

**How can we see details of the object?**

*Write down or draw instruments* or devices *that we can use  
to see details of an object*

| Instruments / Devices | Selection |
| --- | --- |
| **Magnifying glass** |  |
| **Binoculars** |  |
| **Telescope** |  |
| **Optical microscope** |  |
| **Eyes close up** |  |
|  |  |
|  |  |

| ***The students complete their ideas above or draw the above instruments / devices in this space.*** |
| --- |

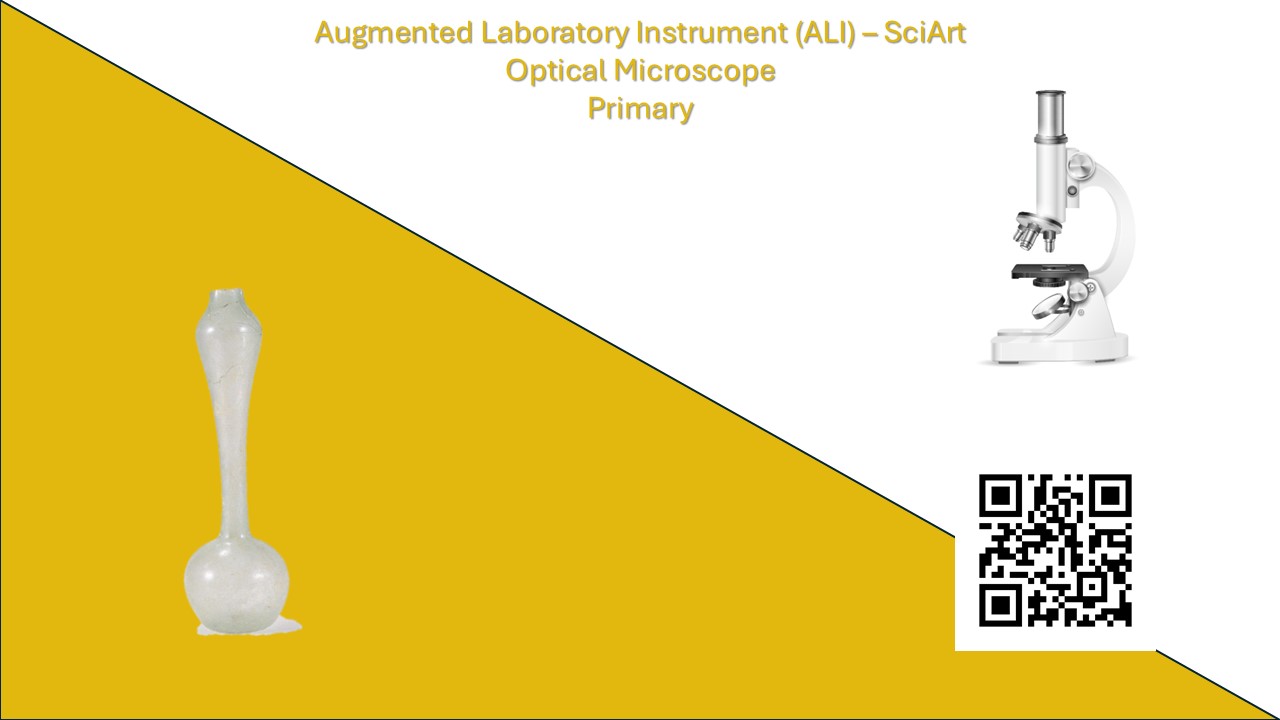
*Discuss as a whole class about the device or the instrument that can give us the best results and choose it from the table above.*

***Through the discussion we come to the optical microscope.***

| *Record the opinions discussed*  *with a short video or sound recording.*  *Call it “1.b Conceptualization”* | | *QR audio* |
| --- | --- | --- |
| **Investigation Research with solid fill** | **QR audio** | |

Use your mobile devices (tablets, mobile phones, etc.) and scan the image below.

Watch the video and download the results provided by the device you selected for the glass vase by clicking on the **"Results"** button.

****

***Discuss with the whole class the results of this particular device***

* In the first area of interest, in the middle of the glass vase, what do you observe? Do we have pure glass everywhere or are there areas with bubbles?





*Image 1 Image 2 Image 3*

***The discussion with the students concludes that with the optical microscope we can identify areas of interest, such as the area in the middle of the glass vase (Image 1) in order to observe how the glass material appears under magnification. By zooming in on the area of interest (middle of the glass vase) we can see that there are a few scattered bubbles (Image 2). The existence of bubbles in the glass means that air was trapped during the manufacturing of the glass vase. Further magnification of the sample (Image 3) reveals that there are areas with bubbles, such as A, and areas without bubbles, such as B. This means that the glass used to make our vase came from recycled glass pieces!***

* In the second area of interest, the crack, what do you observe? What does the crack look like under magnification? What does the higher magnification of the crack reveal? Are there any foreign substances? 



*Image 4 Image 5 Image 6*

***Another point of interest is the area of the crack at the top of the glass vase (Image 4). Zooming in on the area of interest (crack) we see a dark line (Image 5). With more magnification (Image 6) we see the black layer which is the crack, the light grey layer which is the glass and the dark grey (white arrows) which is a foreign substance that is of interest to sample for study. There can be a discussion with students about what the foreign substance might be (e.g. glue?).***

* In the third area of interest, at the bottom of the glass vase, what do you observe? Is there a foreign substance inside the vase? If so, how would you describe it?



*Image 7 Image 8 Image 9*

***Another point of interest for study is the interior of the glass vase (Image 7). By observing the inside of the vase under an optical microscope, we detect foreign substance residues on the bottom (Image 8) and take a sample to study it. With a higher magnification of the Optical Microscope (Image 9), students observe that the unknown substance looks like a powder with irregular grains of different sizes.***

| *Discuss and record what the device is doing with a short video or recording.*  *Why do we use it and what results does it give us?  Call it “1.c Investigation”* | *QR audio* |
| --- | --- |

| **Conclusion Thought outline** | **QR audio** |
| --- | --- |

* **Why do we see three different images for the same point of interest?**

**Can you sort them from the smallest to the largest magnification?**

*Write down your observations or draw the pictures below with arrows for the points of special interest.*

**Every three images give us more and more magnification of the same point.**

**The higher the magnification, the more detail we can observe.**

* **What conclusions can we draw from the three different areas of interest?**

What does the existence of bubbles in the glass mean for the manufacture of the glass vase?

What conclusions do we draw about the crack area?

Is there any residue of a foreign substance inside the vase?

***Write down your observations or draw the pictures below with arrows for the points of special interest.***

**From the images we took from the Optical Microscope for the points of interest we conclude from the existence of bubbles that recyclable glass pieces were probably used for the construction of the vase. The crack appears to have a foreign substance on it and there appears to be foreign substance residue inside the vase. So it's interesting to get more information about these areas.**

| *Record your answers in three different short videos or recordings*  *Name "1.d Conclusion A", "1.d Conclusion B", "1.d Conclusion C"* | | *QR audio* |
| --- | --- | --- |
| **Conceptualization Questions outline** | **QR audio** | | |

*Discuss as a whole class.*

**What do we need to do to get more information  
about the points of interest?**

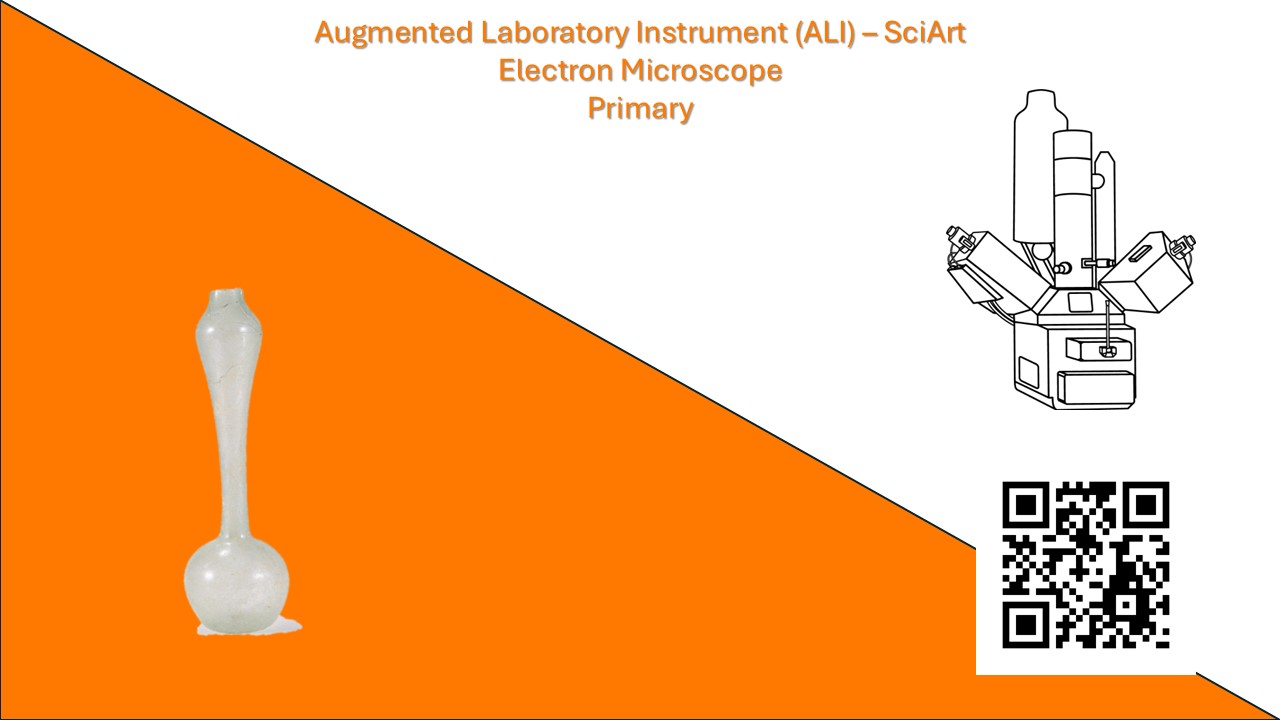
***A plenary discussion is provoked where we direct the students to focus on the need for further enlargement.***

***The teacher introduces the Electron Microscope as a solution for extra magnification.***

| *Record the opinions discussed*  *with a short video or sound recording.*  *Call it “2.b Conceptualization”* | | *QR audio* |
| --- | --- | --- |
| **Investigation Research with solid fill** | **QR audio** | | |

Use your mobile devices (tablets, mobile phones, etc.) and scan the image below.

Watch the video and download the results provided by the device for the glass vase by pressing the **"Results"** button.

****

***Discuss with the whole class the results of this particular device***

* In the first area of interest, from the sample we took from the middle of the glass vase:

What do the black circles on the glass represent?

What does the grey area represent?

Are the bubbles evenly distributed on the glass?

What do you observe in relation to the size of the bubbles? Is it the same?

***In the SEM image of the middle of the glass vase, we can see the bubbles in the glass in black circles, while the whole grey area is the pure glass. We can clearly observe that the bubbles are not evenly distributed throughout the glass, nor are they the same size. So we can conclude that these are pieces of different glass that have been reused (Optionally we can measure the diameter of some bubbles).***

*Image 10*

* In the second area of interest, from the sample taken from the foreign substance in the crack, what do you observe in the SEM image? Is the surface of the sample smooth?



***The SEM image on the left shows the foreign substance of the sample taken from the crack. Observe that the surface of the sample is not smooth.***

*Image 11*

* In the third area of interest, from the sample we took of the foreign substance on the bottom inside the vase, what do you observe in the SEM image? How would you describe the foreign substance? Can we figure out what the substance is or do we need to apply another method?Εικόνα που περιέχει κείμενο, ύφαλος, στιγμιότυπο οθόνης, ασπρόμαυρο

  Περιγραφή που δημιουργήθηκε αυτόματα

***The SEM image on the left shows the foreign substance from the residues we took from the bottom inside the vase. From their morphological characteristics, no conclusion can be drawn as to what the foreign substance is.***

*Image 12*

| *Describe how the device works and for what purpose we use it*  *with a short video or audio recording.*  *Call it “2.c Investigation”* | | *QR audio* |
| --- | --- | --- |
| **Conclusion Thought outline** | **QR audio** | | |

* **Of the three different areas of interest depicted with the SEM method, which one do you think has the highest magnification? How can we find it?**

**The highest magnification is Image 11 with 1000x. We can read the magnification directly from the information given at the bottom of the image.**

***In the three images there is a magnification of 200x (Image 10) 1000x (Image 11) and 500x (Image 12). We can read the magnification from the information given at the bottom of the image.***

* **Why do we see black and white images?**

**We get black and white images because SEM does not use natural light but electrons.**

***We help students to come to the above conclusion, also using the information in the video.***

* **What do we observe in the images? What might they mean about our object? Can we draw conclusions about the components at the points of interest (glass, crack and substance residue on the bottom)?**
* **No matter how large the magnification of the work, it cannot give us clear answers about the components that make up the glass and the foreign substances in the crack and inside the vase.**
* **So we select the points of interest identified by the SEM method to find the components that make up the glass and the foreign substances in the crack and inside the glass, using a new method, EDS.**

| *Record your answers in three different short videos or recordings*  *Name them "2.d Conclusion A", "2.d Conclusion B", "2.d Conclusion C"* | | *QR audio* |
| --- | --- | --- |
| **Conceptualization Questions outline** | **QR audio** | |

*Discuss as a whole class.*

**What do we need to do to find the components**

**of the areas of interest of the subject we are studying?**

**What do we need to recognise?**

***A plenary discussion is provoked leading to the identification of the components that make up the materials in the areas of interest (glass in the middle of the vase, foreign substance in the crack, foreign substance inside the glass vase).***

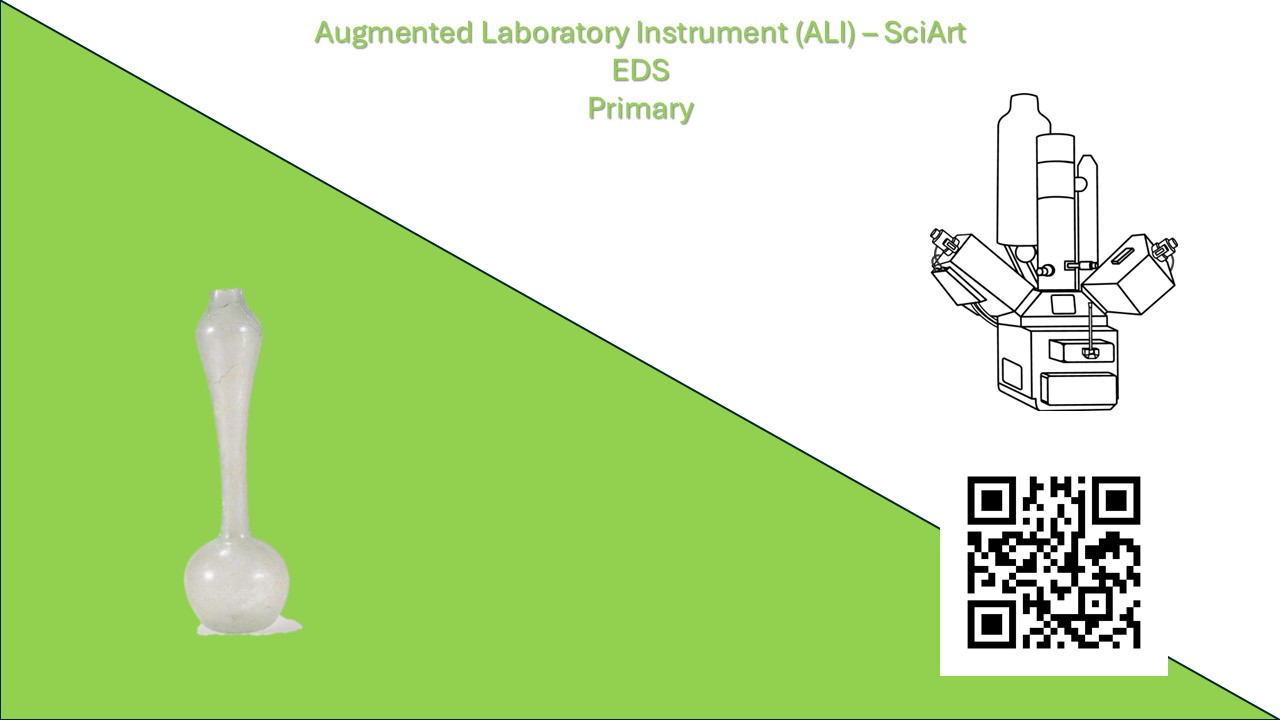
***The teacher introduces the EDS method for the elemental analysis of the selected areas. "EDS, is an analytical method used to identify the elements found in a sample".***

| *Record the opinions discussed*  *with a short video or sound recording.*  *Call it “3.b Conceptualization”* | *QR audio* |
| --- | --- |

| **Investigation Research with solid fill** | **QR audio** |
| --- | --- |

Use your mobile devices (tablets, mobile phones, etc.) and scan the image below.

Watch the video and download the results provided by the device for the glass vase by pressing the "**Results**" button.

****

***Study in your group and then discuss as a whole class***

***the results of the particular method***

***Students observe the spectrum and the element table and identify the elements that make up the sample.***

***The teacher explains to the students that EDS spectra are obtained only by selecting points or areas of interest from SEM images and asks the students to identify the elements detected in the spectrum by the EDS method.***

* In the first area of interest, from the sample taken from the glass in the middle of the vase, what do you observe in the EDS spectrum? What elements are detected?



***This is the spectrum we get from the EDS method for the glass of the vase. It mainly consists of silicon (~70%), calcium (~10%), sodium (1.2%), aluminum (~2.2%), potassium (~2.5%), iron (~1%), manganese (~1%), phosphorus (~0.5%) and antimony (~1.8%).***

*Image 13*

* In the second area of interest, from the sample taken from the crack, what do you observe in the EDS spectrum? What elements does the foreign substance consist of?

Εικόνα που περιέχει κείμενο, στιγμιότυπο οθόνης, γραμμή, διάγραμμα

Περιγραφή που δημιουργήθηκε αυτόματα

***This is the spectrum obtained from the EDS method for the component detected in the crack. It consists of carbon and oxygen, which is a typical feature of substances of organic origin.***

*Image 14*

* In the third area of interest, from the sample we took of the residues inside the vase, what do you observe in the EDS spectrum? What elements does the unknown substance consist of?

Εικόνα που περιέχει κείμενο, στιγμιότυπο οθόνης, γραμμή, διάγραμμα

Περιγραφή που δημιουργήθηκε αυτόματα

***This is the spectrum we get from the EDS method for the unknown substance found inside the vase. It consists of carbon and oxygen, which is a typical feature of substances of organic origin.***

*Image 15*

| *Discuss and document how the method works*  *with a short video or audio recording.*  *What results did it give us?*  *What else did we have to do?*  *Call it “3.c Investigation”* | | *QR audio* |
| --- | --- | --- |
| **Conclusion Thought outline** | **QR audio** | | |

List the materials in which the elements found in our sample are found in the table below.

**In the first area of interest, from the results you got, what conclusions do you draw about glass? Which of the elements detected by the method is related to the green tint of the glass? Vased on the results you obtained, can you explain why the glass of the vase is opaque?**

**Iron is responsible for the green tint of glass**

**Ash is used as an opacifier in glass manufacturing, which confirms that glass has been reused**

* **In the second area of interest, in the crack, what kind of substance was found?**

**Can you make any assumptions about what it might be?**

**Flowers or a plant, oil, wood....**

* **In the third area of interest, inside the vase, what kind of substance was found?**

**Can you make any assumptions about what it might be?**

**Flowers or a plant, oil, wood, fruit residues...**

| *Record your answers*  *in a short video or sound recording.*  *Explain how you got there.*  *Call them "3.d Conclusion"* | *QR audio* |
| --- | --- |

| **Conceptualization Questions outline** | **QR audio** |
| --- | --- |

*Discuss as a whole class.*

**What do we need to do to get more information about the points of interest?**

**Can we use FTIR method to see what additional information it can give us?**

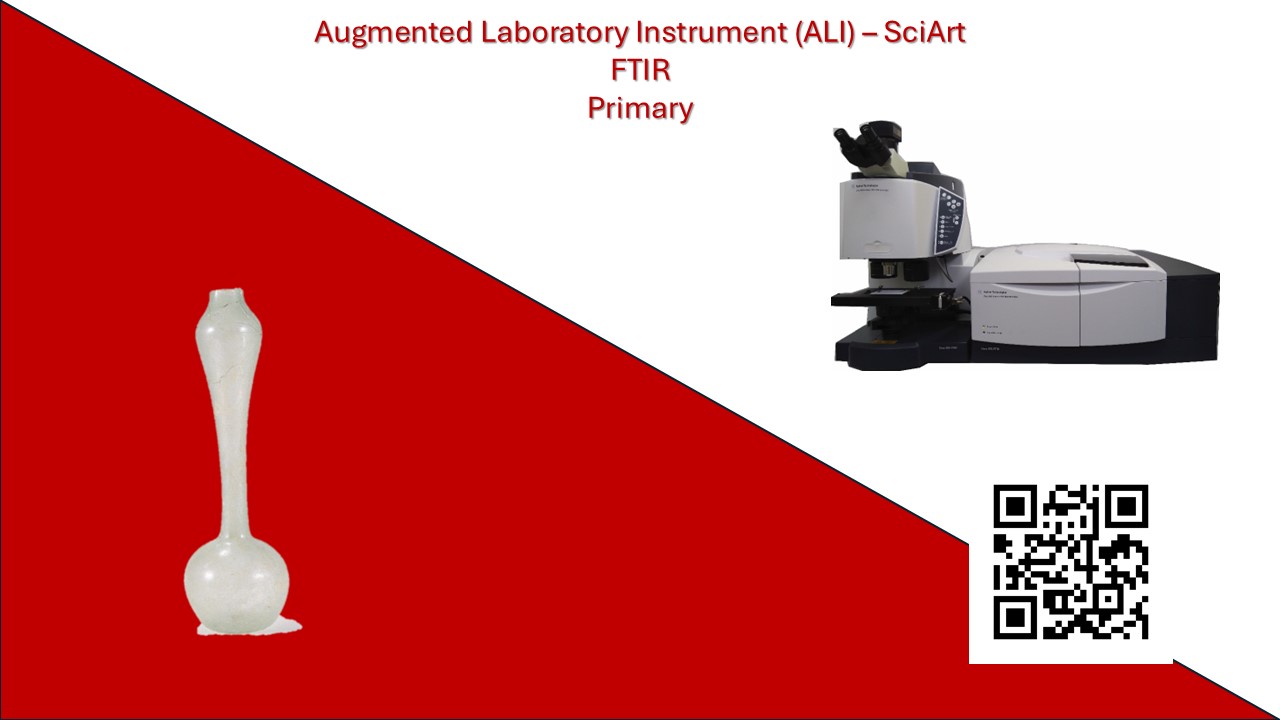
***A plenary discussion is provoked where we direct the students to focus on the need for further investigation with FTIR.***

| *Record the opinions discussed*  *with a short video or sound recording.*  *Call it “4.b Conceptualization”* | *QR audio* |
| --- | --- |

| **Investigation Research with solid fill** | **QR audio** |
| --- | --- |

Use your mobile devices (tablets, mobile, etc.) and scan the image below.

Watch the video and download the results provided by the device for the glass vase by clicking on the **"Results"** button.

****

***Discuss in the whole class the results of this particular method***

* In the first area of interest, does the FTIR spectrum confirm that the material of the vase is glass; What is the chemical formula of glass?

Εικόνα που περιέχει γραμμή, γράφημα, διάγραμμα

Περιγραφή που δημιουργήθηκε αυτόματα

***The FTIR method gives us results for the glass material of the vase. The two inverted peaks at 1011 cm-1 and 779 cm-1 confirm that the material of which the vase is made is glass (amorphous silica SiO2).***

*Image 16*

* In the second area of interest, what is the foreign substance detected by FTIR in the crack?

Εικόνα που περιέχει κείμενο, διάγραμμα, γράφημα, γραμμή

Περιγραφή που δημιουργήθηκε αυτόματα

***The unknown substance in the crack is identified with a preservation material called Paraloid B-72.***

*Image 17*

* In the third area of interest, what is the foreign substance detected by FTIR inside the vase?

Εικόνα που περιέχει διάγραμμα, γραμμή, γράφημα, κείμενο

Περιγραφή που δημιουργήθηκε αυτόματα

***The FTIR method gives a spectrum with inverted peaks for the area inside the vase indicating that the foreign substance is myrrh.***

*Image 18*

| *Discuss and record how the FTIR method works*  *with a short video or sound recording.*  *What results did it give us?*  *Call it “4.c Investigation”* | | *QR audio* |
| --- | --- | --- |
| **Conclusion Thought outline** | **QR audio** | | |

* **The FTIR method identified the components of the glass and foreign substances in the crack and residues found inside the glass. Can you summarize the results of the FTIR method in the table below?**

| **Points of interest** | **Chemical Compounds** |
| --- | --- |
| Glass material in the middle of the vase | **Amorphous silicon dioxide SiO2** |
| Foreign substance in the crack | **Paraloid B-72** |
| Foreign residue substance inside the glass vase | **Myrrh** |

| *Record your answers in a short video or audio recording*  *Explain how you got there.*  *Name them "4.d Conclusion"* | | *QR audio* |
| --- | --- | --- |
| **Conceptualization Questions outline** | **QR audio** | | |

*Discuss as a whole class.*

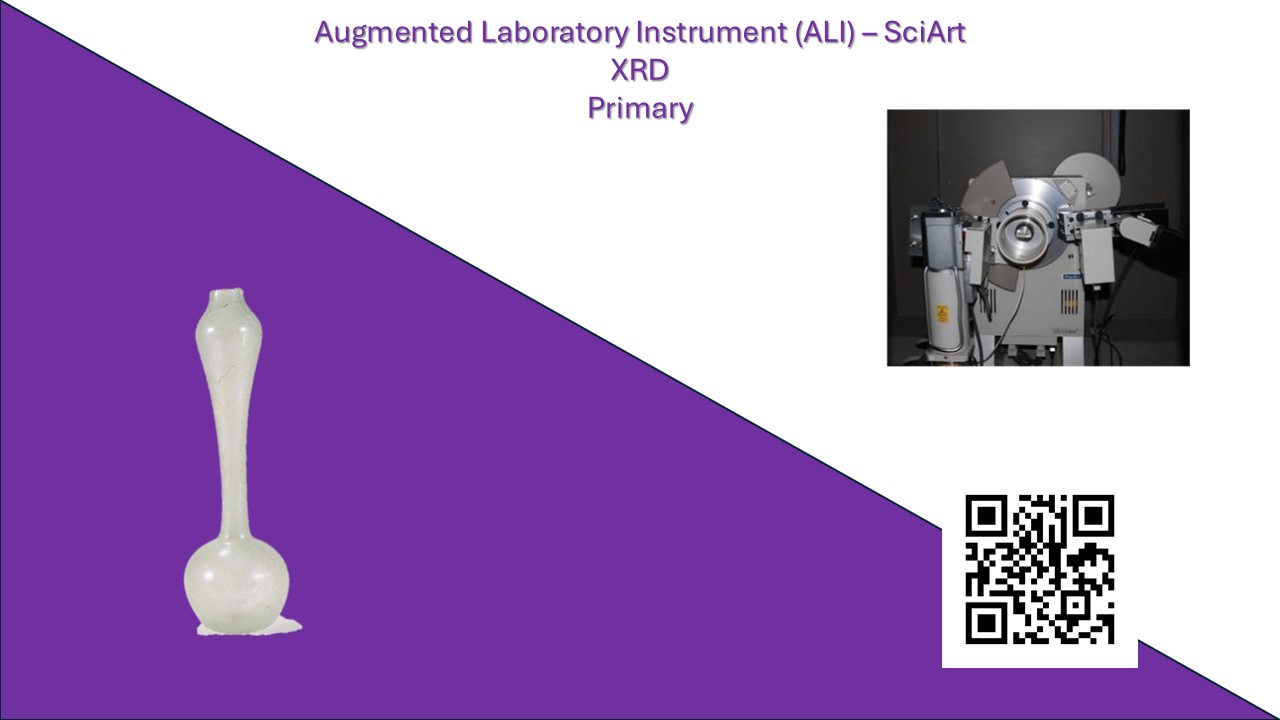
**What would the XRD method show differently for the three points of interest?**

***The teacher introduces the need to apply another method to accurately identify the composition of materials, the XRD method.***

| *Record the opinions discussed*  *with a short video or sound recording.*  *Call it “5.b Conceptualization”* | | *QR audio* |
| --- | --- | --- |
| **Investigation Research with solid fill** | **QR audio** | | |

Use your mobile devices (tablets, mobile, etc.) and scan the image below.

Watch the video and download the results provided by the device for the glass vase by clicking on the **"Results"** button.

****

*Discuss in the whole class the results of this particular method*

***Students observe the graph (diffractogram) and the table of chemical compounds identified.***

* In the first area of interest, from the glass sample, vased on the XRD pattern (diffraction pattern), which compound is confirmed?

Εικόνα που περιέχει διάγραμμα, κείμενο, γράφημα, γραμμή

Περιγραφή που δημιουργήθηκε αυτόματα

***The XRD diffraction pattern for the glass material of the vase confirms that we have amorphous SiO2.***

*Image 19*

* In the second area of interest, from the crack sample, vased on the XRD pattern (diffraction pattern), which compound is confirmed?

Εικόνα που περιέχει κείμενο, γράφημα, διάγραμμα, γραμμή

Περιγραφή που δημιουργήθηκε αυτόματα

***The XRD diffraction pattern for the foreign substance in the crack confirms that we have something organic.***

*Image 20*

* In the third area of interest, from the remains inside the vase, vased on the XRD graph (diffraction pattern), which compound is confirmed?

Εικόνα που περιέχει κείμενο, γράφημα, διάγραμμα, γραμμή

Περιγραφή που δημιουργήθηκε αυτόματα

***The XRD diffraction pattern for the substance inside the glass confirms that we have something organic.***

*Image 21*

| *Discuss and record how the method works*  *with a short video or sound recording.*  *What results did it give us?*  *Call it “5.c Investigation”* | | *QR audio* |
| --- | --- | --- |
| **Conclusion Thought outline** | **QR audio** | | |

* **Record the material/chemical compound you have identified using the XRD method.**

| **Points of interest** | **Material - chemical compound** |
| --- | --- |
| Glass from the middle of the vase | **amorphous SiO2** |
| Substance found in the crack | **Organic substance Paraloid B-72, as confirmed by FTIR** |
| Residues inside the glass vase | **Organic myrrh substance as confirmed by FTIR** |

**But what is the Paraloid B-72? What do we know about myrrh?**

**Can we investigate what it is?**

| *Record your answers*  *in a short video or sound recording.*  *Explain how you got there.*  *Name them “5.d Conclusion”* | *QR audio* |
| --- | --- |

| **Conceptualization Questions outline** | **QR audio** |
| --- | --- |

*Discuss as a whole class.*

**How can we use the conclusions we have drawn from archaeometric methods to answer the initial questions?**

*Write questions that you can ask an AI machine (ChatGPT), to collect information about what amorphous silica (silicon dioxide, SiO2 ) is, what Paraloid B-72, found in the crack is, and where it is used, as well as what myrrh is, found inside the vase, and where it is used.*

*List questions you could ask on the table.*

***ChatGPT questions can be in Greek because they give correct answers. The teacher facilitates a plenary discussion to formulate the questions the students need to answer the above questions. Such questions can be:***

| **What is amorphous silica (SiO2)?** |
| --- |
| **When was amorphous silica (SiO2) used to make glass?** |
| **What is the Paraloid B-72** |
| **How is Paraloid B-72 used in glass conservation?** |
| **What is myrrh?** |
| **How was myrrh used in the 4ο century AD?** |

| *List the questions you will ask in ChatGPT*  *with a short video or sound recording.*  *Call it “6.b Conceptualization”* | *QR audio* |
| --- | --- |
| **Investigation Research with solid fill** | **QR audio** |

Use ChatGPT to collect information on the above questions. Record the information you need to answer the questions, in the table below.

| **Question** | **Reply** |
| --- | --- |
| What is amorphous silica (silicon dioxide, SiO2)? | **It is a form of silicon that has no crystalline form** |
| When was amorphous silica (silicon dioxide, SiO2) used to make glass? | **Used since ancient times for the manufacture of glass** |
| What is the Paraloid B-72 | **It's a kind of glue** |
| How is Paraloid B-72 used in glass conservation? | **Used for the conservation of works of art** |
| What is myrrh? | **It is a resin of vegetable origin** |
| How was myrrh used in the 4ο century AD? | **In rituals it was burned as an aromatic, in perfumery it was used as a perfume, in medicine it was used as an anti-inflammatory-antiseptic.** |
| What ingredients are in glass objects made today? Do they have common elements with the ingredients used in ancient times? | **The basic raw materials are the same, such as silica (silicon dioxide, SiO2). In ancient times, the glass production process was more primitive and also depended on the available materials in each area.** |
|  |  |

*Discuss the answers as a whole class*

*to the specific questions you asked in ChatGPT.*

*Record the answers to the initial inquiry questions.*

| *Note the main points of the answers for each question.  Did it help you find the answer? How?*  *Call it “6.c Investigation”* | | *QR audio* |
| --- | --- | --- |
| **Conclusion Thought outline** | **QR audio** | | |

* **Summarise your conclusions from the results of the methods you applied and the information you collected from ChatGPT for the three points of interest in the table below.**

| **Points of interest** | **chemical compounds** | **What is it?** | **How and where is it used?** |
| --- | --- | --- | --- |
| Glass material in the middle of the vase | **Silicon dioxide SiO 2** | **It is a form of silicon that has no crystalline form** | **Used since ancient times for the manufacture of glass** |
| Foreign substance found in the crack | **Paraloid B-72** | **It's a kind of glue** | **Used for the conservation of works of art** |
| Foreign residue substance found inside the glass vase | **Myro** | **It is a resin of vegetable origin** | **In rituals it was burned as an aromatic, in perfumery as a perfume, in medicine as an anti-inflammatory-antiseptic.** |

**Back to the initial questions...**

1. What was the (social) position of the craftsmen in Byzantium? Can we investigate the components of the glass used in the 4th century AD?

2. Have these products been exported and to where? Can we find similar products in Portugal, Cyprus or elsewhere?

3. Can we compare it with a glass product manufactured today? Are there any similarities/differences?

4. Can we make assumptions about the use of these glass products? What tests can we perform?

| **1. What was the (social) position of the craftsmen in Byzantium? Can we investigate the components of the glass used in the 4th century AD?** |
| --- |
| ***Amorphous silicon dioxide (SiO2 ) for the manufacture of glass has been used since ancient times!*** |
| **2. Have these products been exported and to where? Can we find similar products in Portugal, Cyprus or elsewhere?** |
| ***.............................*** |
| **3. Can we compare it with a glass product manufactured today? Are there any similarities / differences?** |
| ***The basic raw materials are the same, such as silica (SiO2). In ancient times, the glass production process was more primitive and also depended on the materials available in each area......*** |
| **4. Can we make assumptions about the use of these glass products? What tests can we perform?** |
| ***........................*** |

|  | *QR audio* |
| --- | --- |

**Create a video of your answer to each question  
in the form of an interview.**

**One or the other of you will ask the question**

**and one or the other will answer!!!**

*Name the videos "Final Answer 1", "Final Answer 2", etc.*