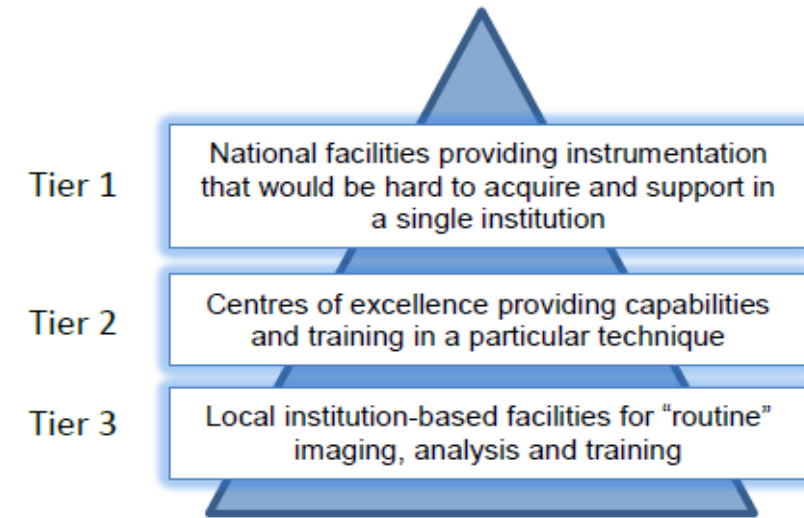


Physical Sciences EM UK Roadmap Refresh

- July 2022 – Initial meeting following EMAG meeting at Imperial
- New RMS/IoP Survey to EM users (129 responses) and Lab. Leaders (44 responses) early 2023
- Five groups formed (from initial meeting and RMS and IoP input)
 - **Current Ecosystem** (Brydson, Brown, Lazarov)
 - **Training and RTP Development** (Haigh, Clark, McGilvery, Ducati)
 - **Access** (Maclaren, Lim, Chiu, Allen, Fleck)
 - **Data Management, Processing and Modelling** (Nicholls, Slater, Conroy, Kerrigan, Schuster)
 - **Techwatch/Horizon Scanning** (Ramasse, Kirkland, Yuan, Browning, Beanland)
- Update Meetings MMC July 2023 and UK-EMI meeting 2024



Overview since last Roadmap

- A variety of SEM, FIBSEM and TEM investment by UKRI and also Institutions
- Renewal of SuperSTEM National Facility and development of ePSIC facility Harwell
- Expansion of trained users at the National Facilities
- Previous EPSRC equipment Access Schemes (Leeds/Nottingham/ St Andrews). EPSRC still welcome *resource only* Strategic Equipment bids.
- Royce equipment access/training scheme for PhD researchers and RTPs – now handled centrally by Royce. Includes funds for accessing training but also running training courses.
- CDT in Advanced Characterisation of Materials (Imperial/UCL/Trinity) – now at end of second reincarnation, but not renewed.
- Transnational Access via EU Horizon2020 ESTEEM3 scheme – now closed
- Rosalind Franklin Imaging funding and announcement of RUEDI funding

Key issues which have arisen since last Roadmap

Sustainability

- Increasing Service Costs
- Student Access Issues – PhDs and PGTs have very limited resource
- Charging Models (increasing pressure to include space and depreciation in TRAC)
- Development of RTP staff
- Benchtop instrumentation (SEM)
- Increasing costs of new detectors/spectrometers
- Core equipment replacement

Other

- Training in Sample Preparation
- Data Storage/Transfer
- Increase in Modelling of Results
- Access to specialist techniques
- Increasing Research Bureaucracy associated with Facilities.

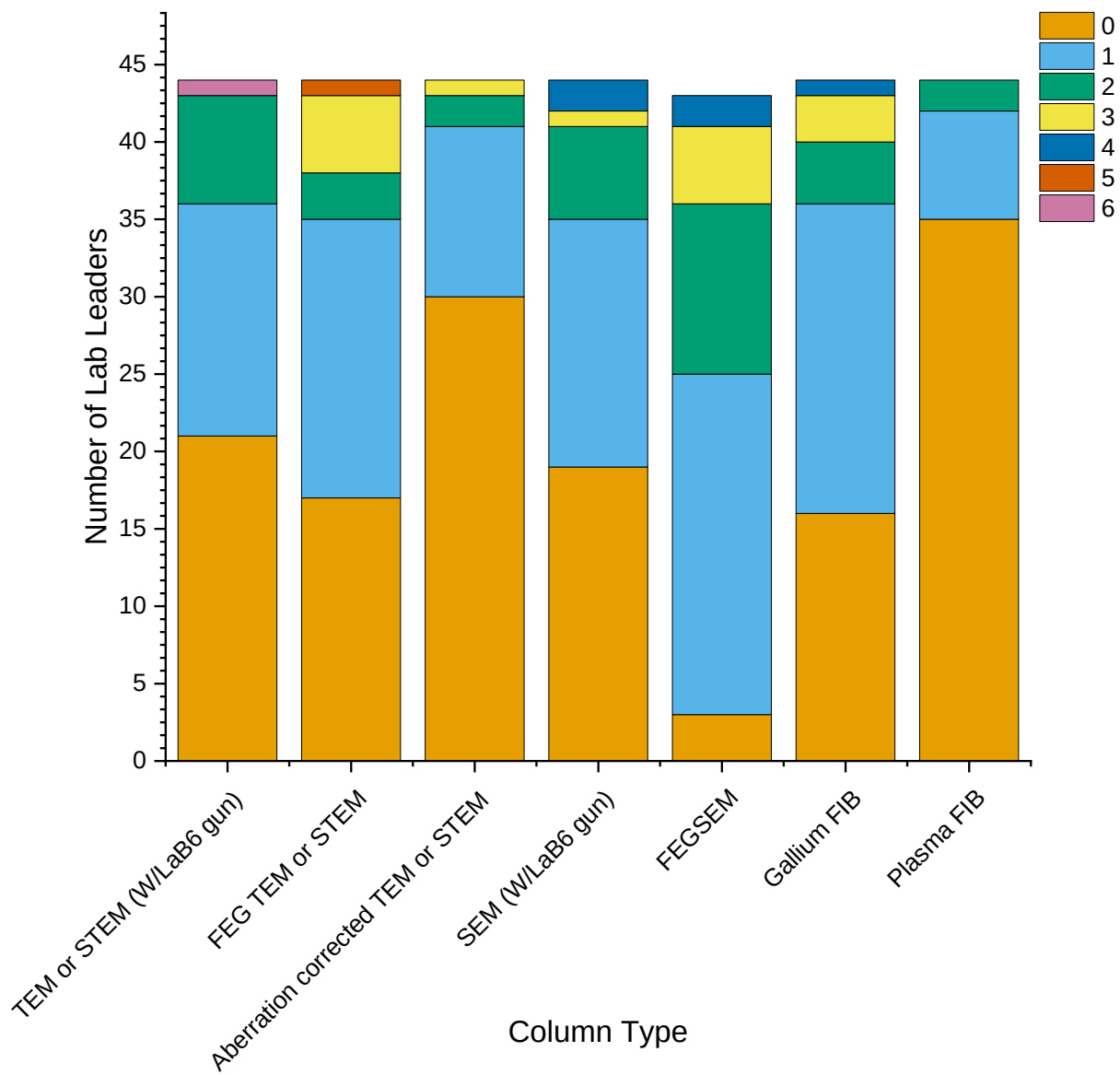
The Current Ecosystem EM Survey Results

Rik Brydson, Paul Brown, Vlado Lazarov

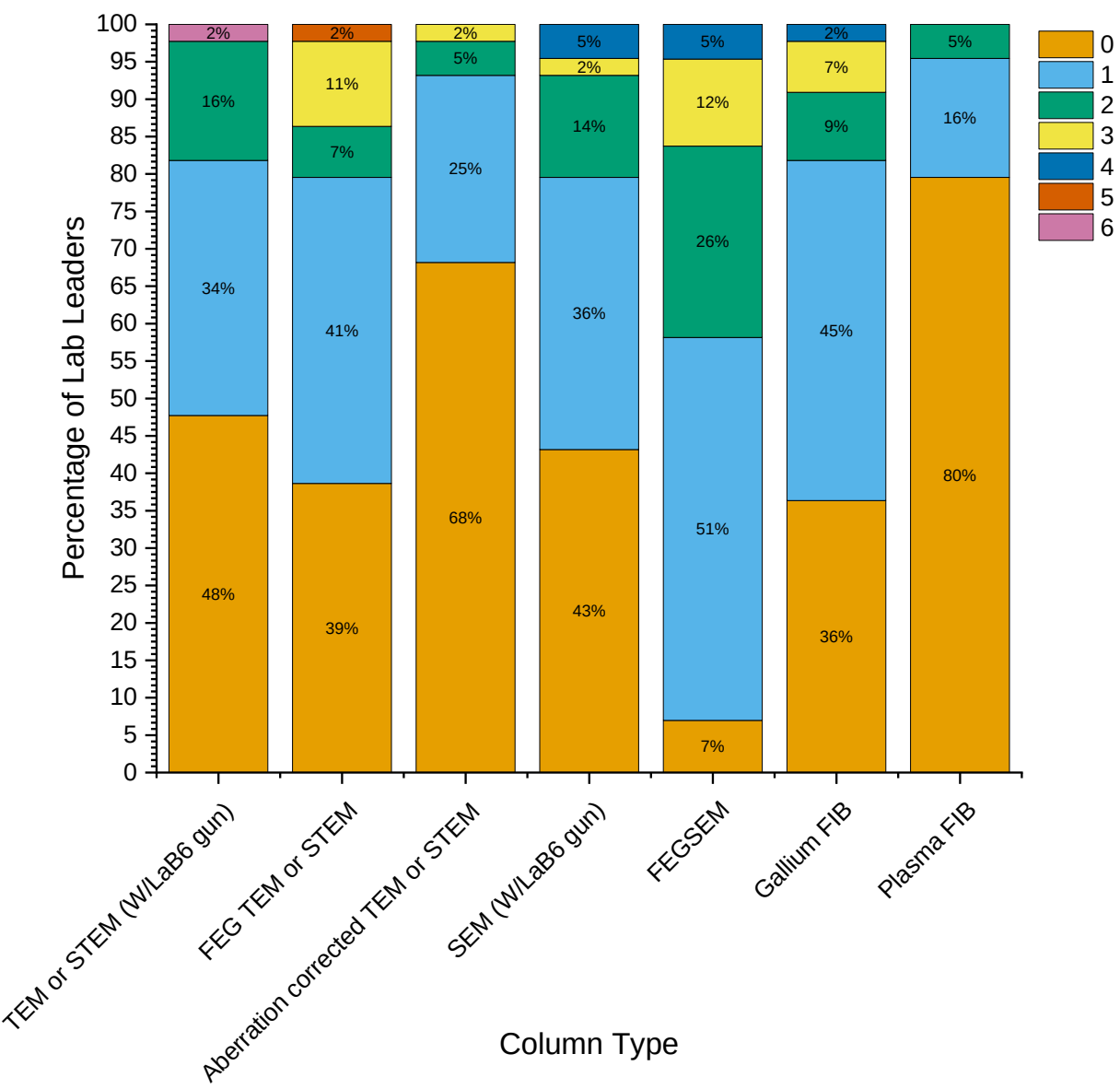
Lab Leaders Survey

(24 questions) - **44 responses**

How many electron microscope columns do you operate?

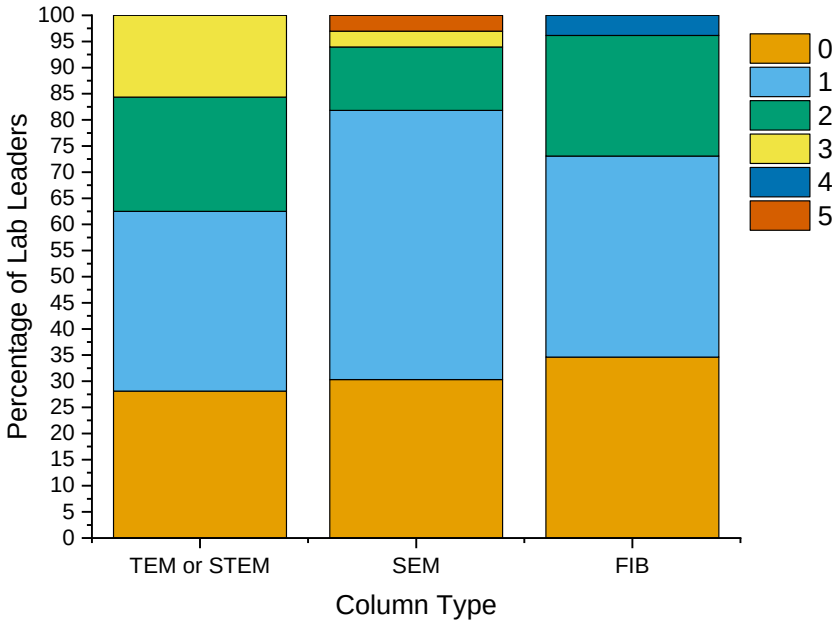
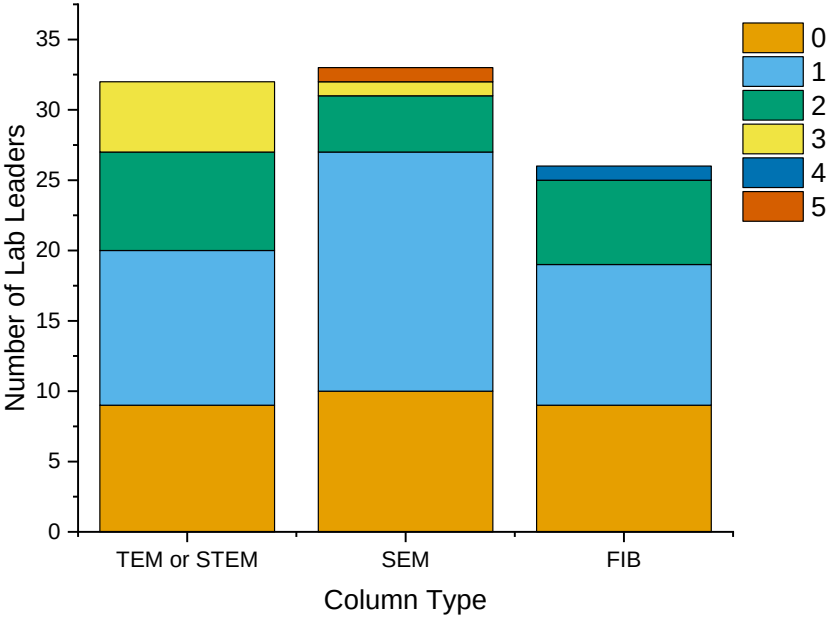


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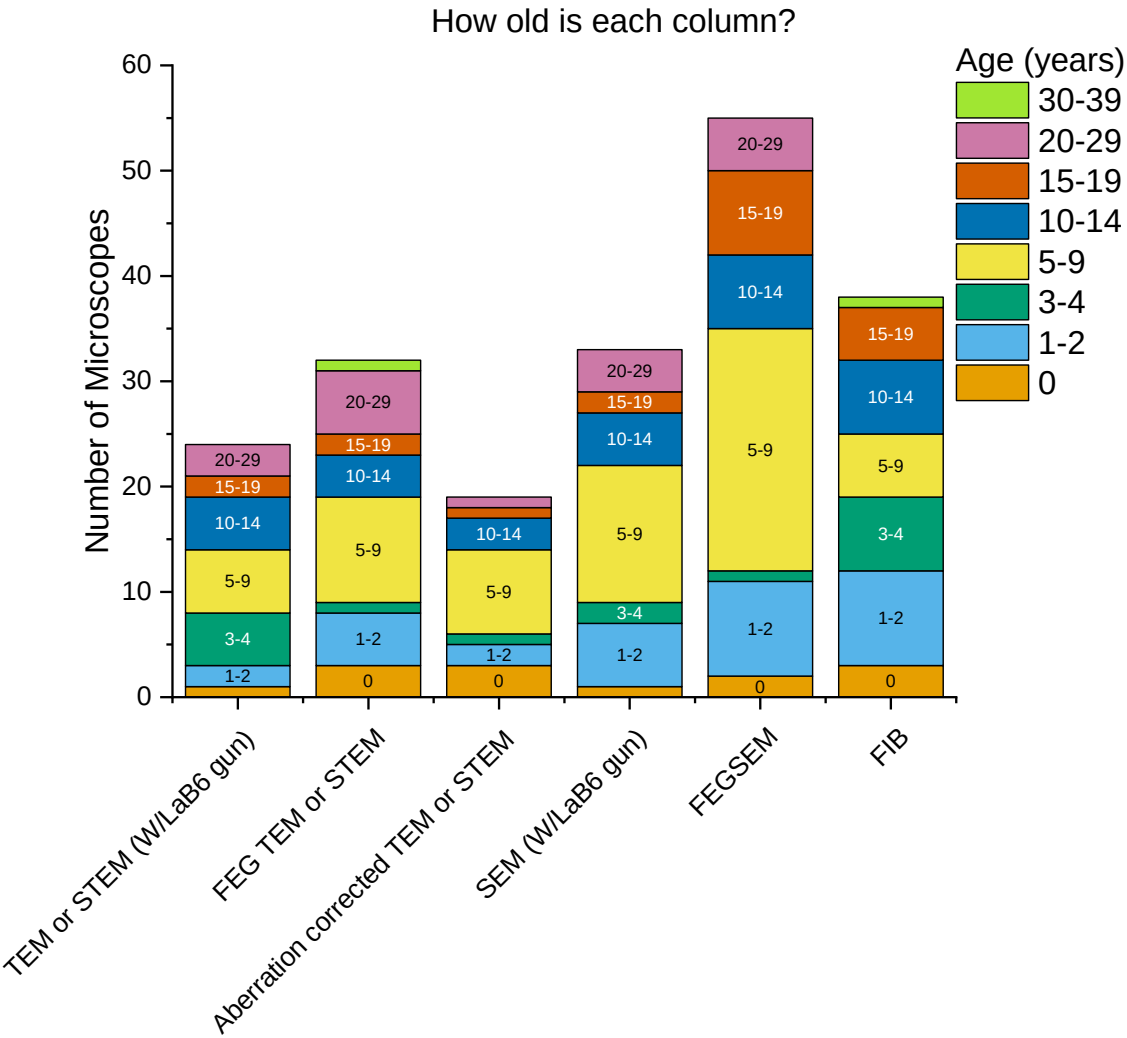


How many of these electron microscope columns offer in-situ capabilities (including heating, cryo-, gas cell, liquid cell, electrical biasing etc.)?

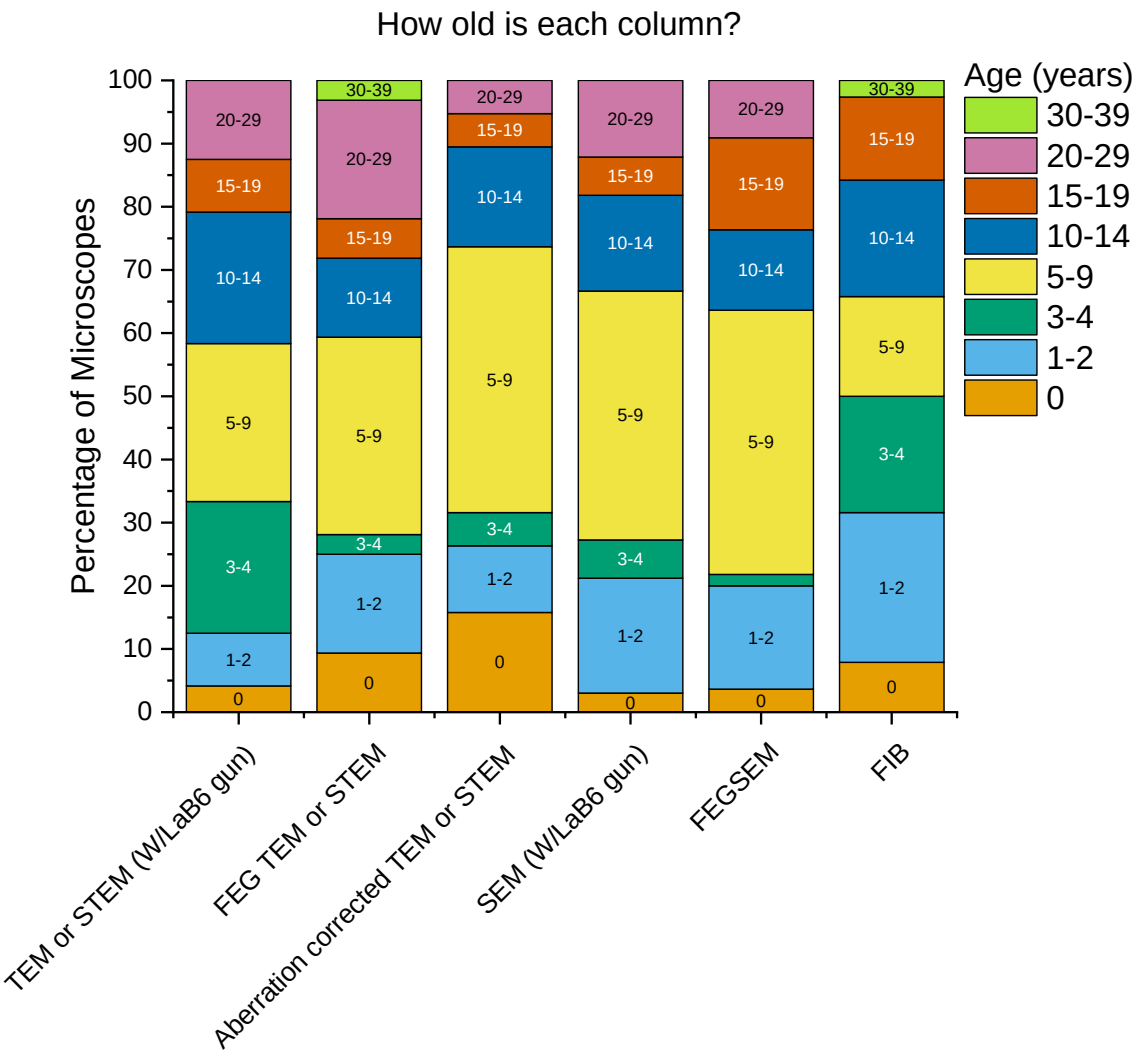
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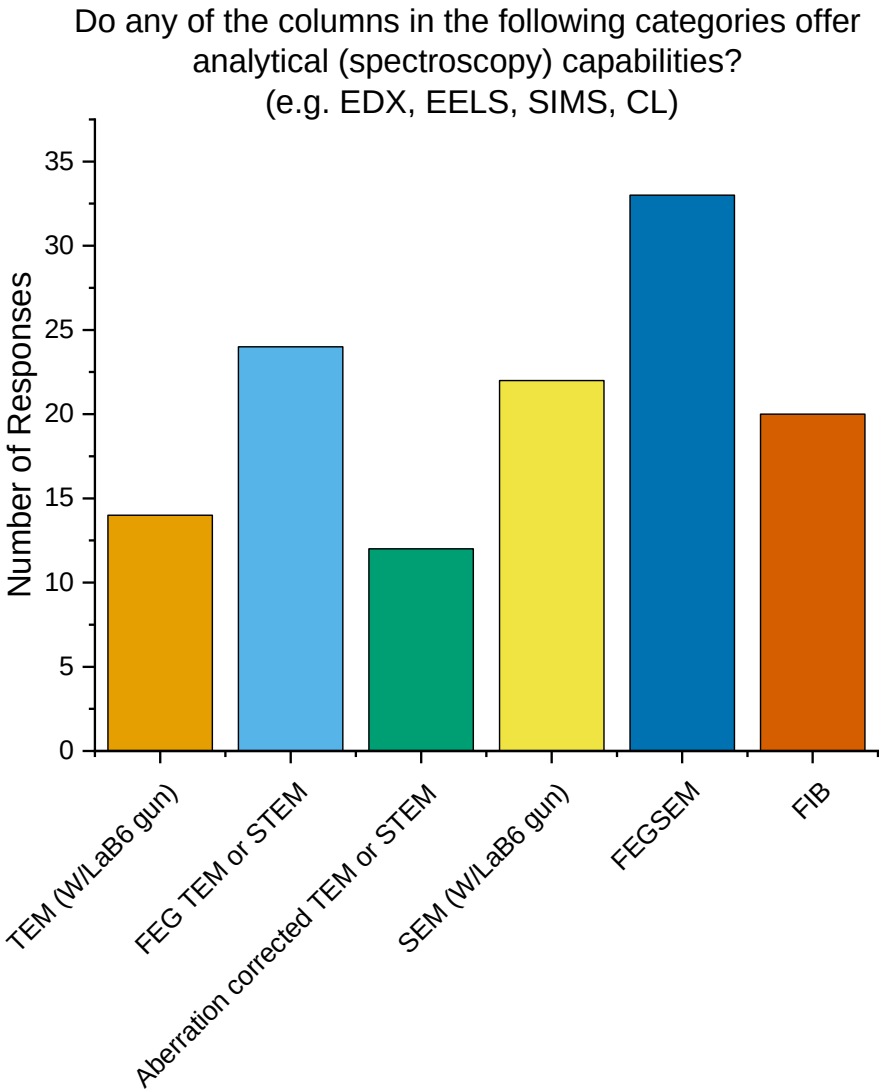
Raw number of microscopes



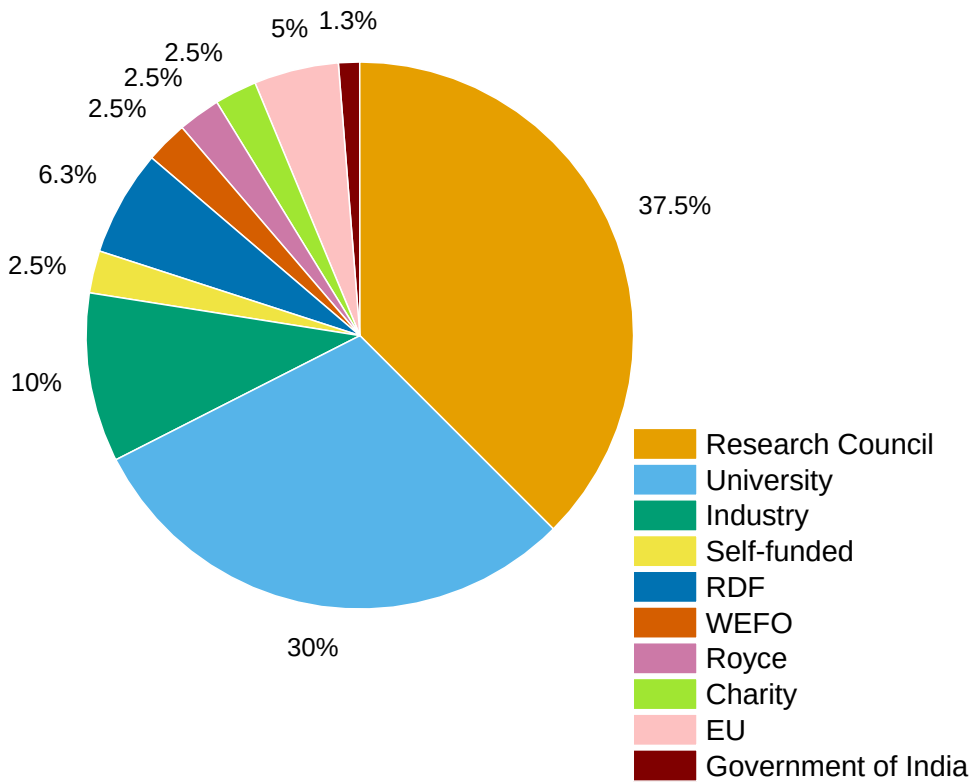
Percentage of microscopes



Note: Answers were a bit varied here due to some listing several ages for multiple microscopes, or giving a large age range encompassing all the ages of the instruments, so harder to get 100% accurate info from answers given

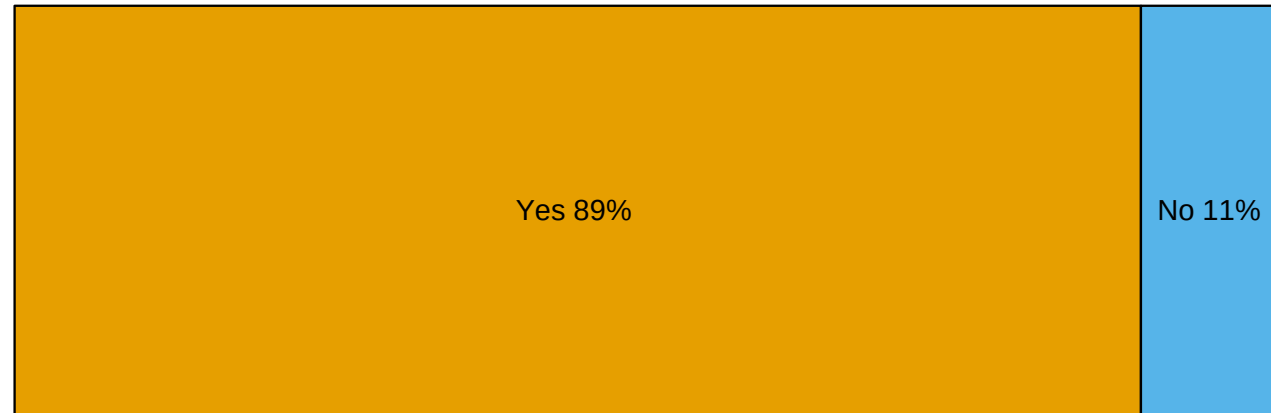


How was the equipment funded?



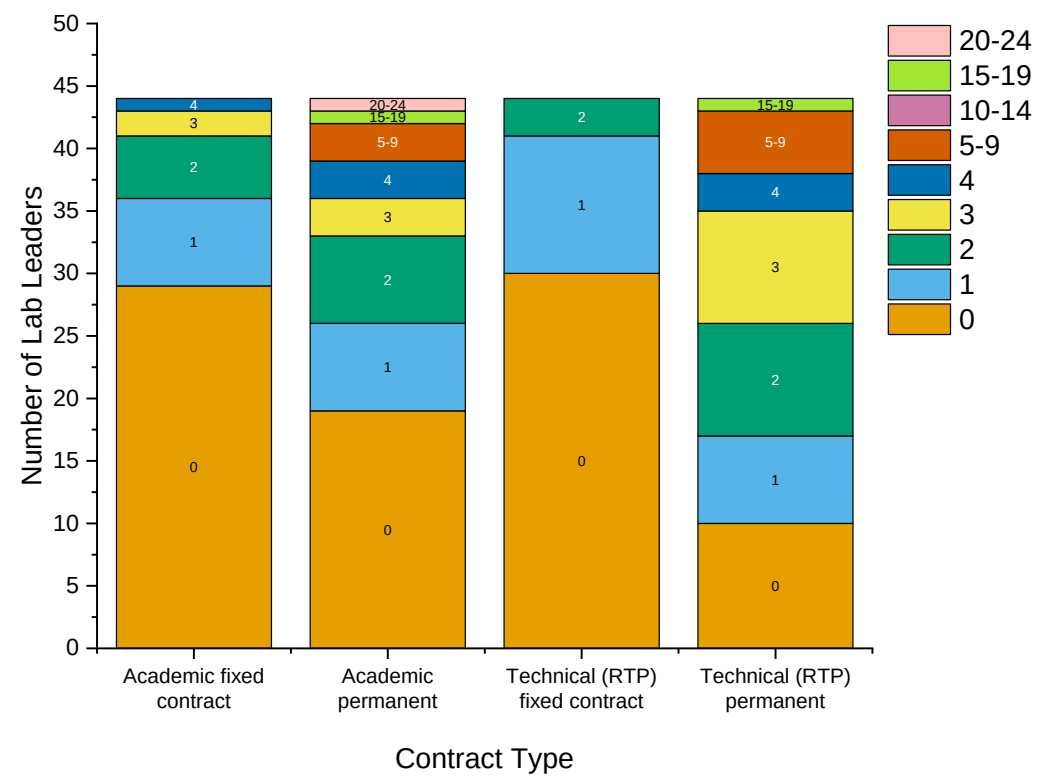
Note: responses generally gave a mixture of these sources rather than one source

Do you offer specimen preparation as a service to internal or external users?



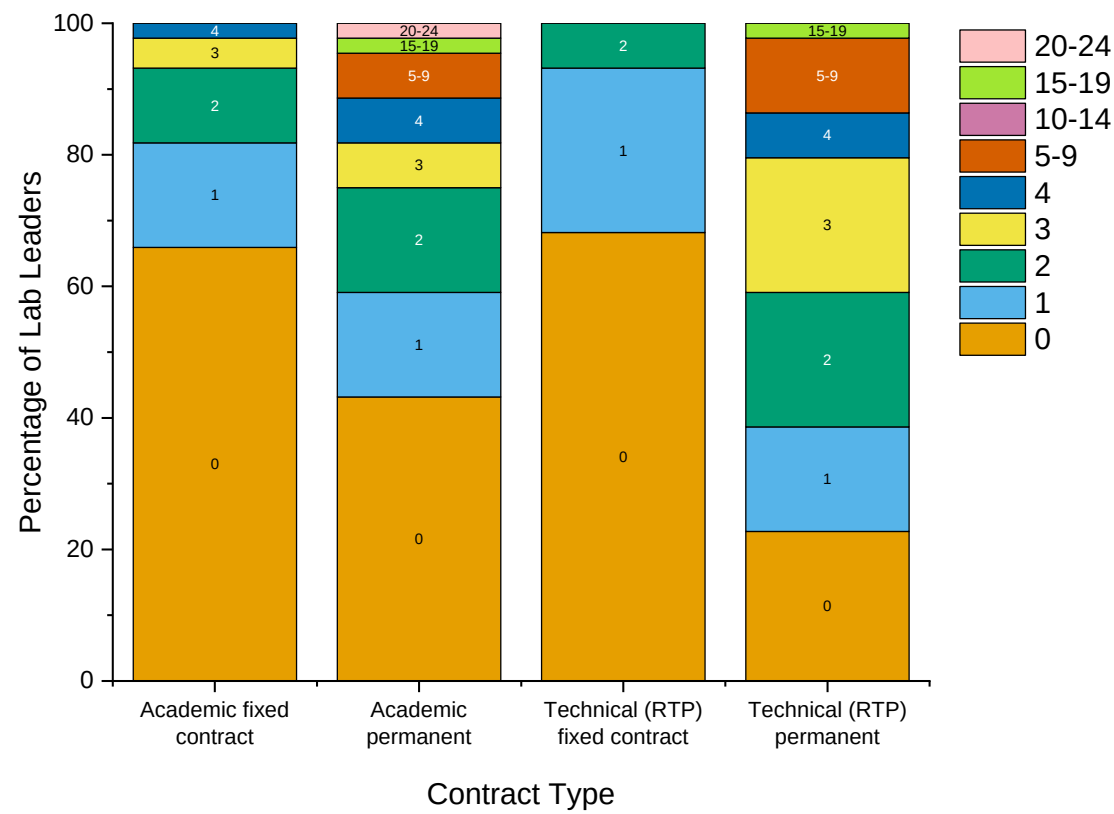
Raw number of responses

How many academic and technical staff are associated with supporting the equipment?

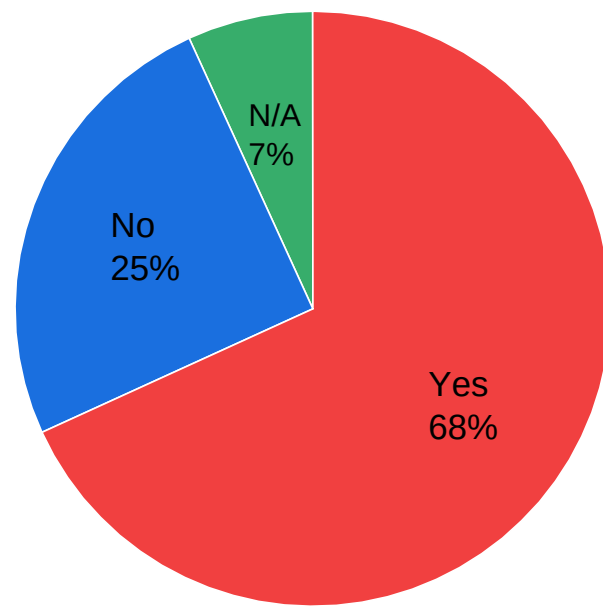


Percentage of responses

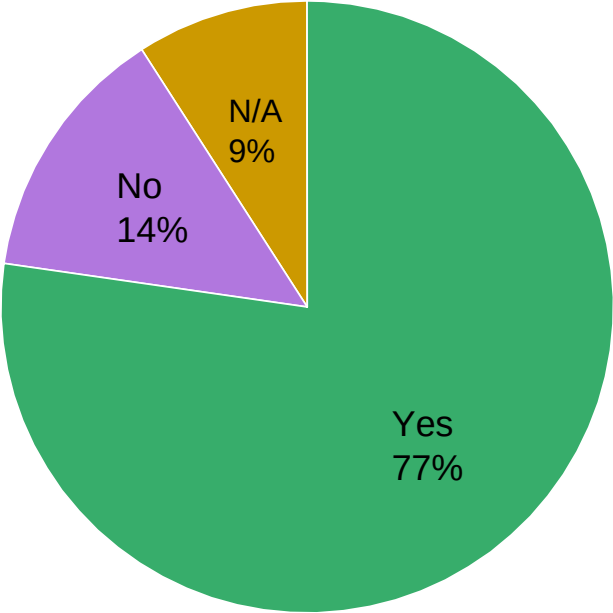
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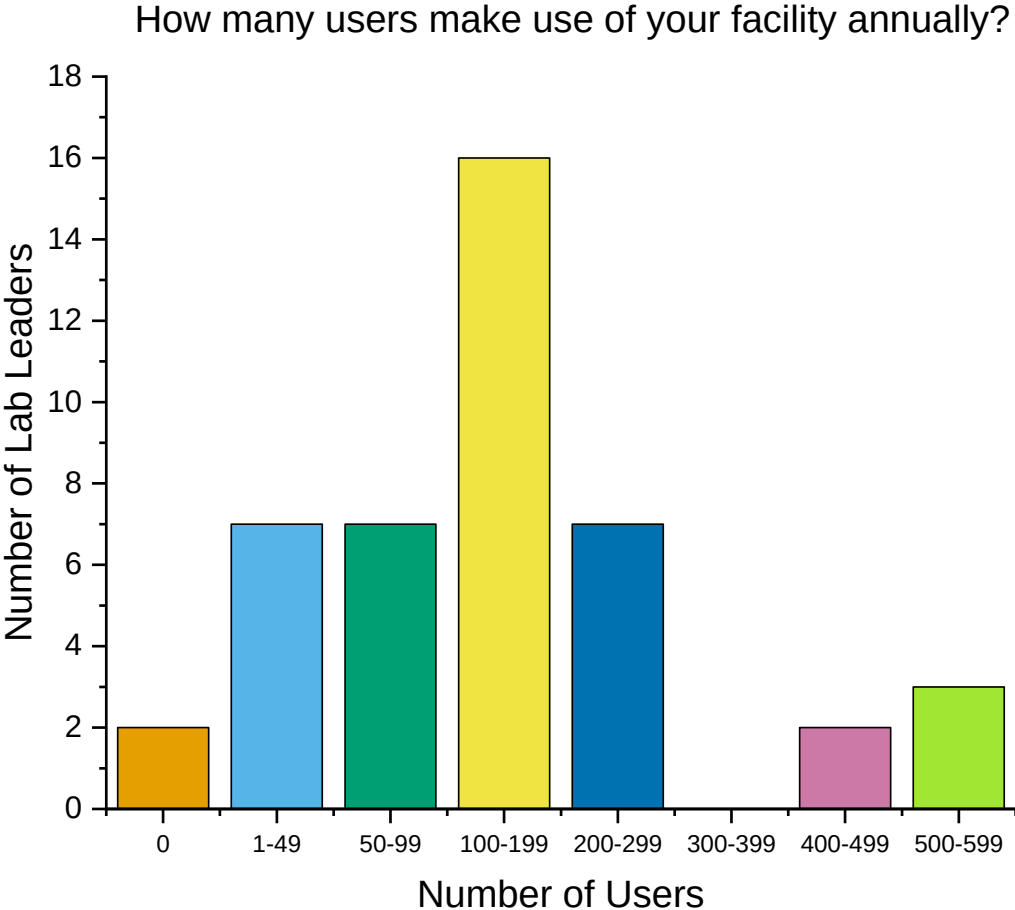


Have RTP (technical) staff in your team participated in professional development training over the last 5 years?

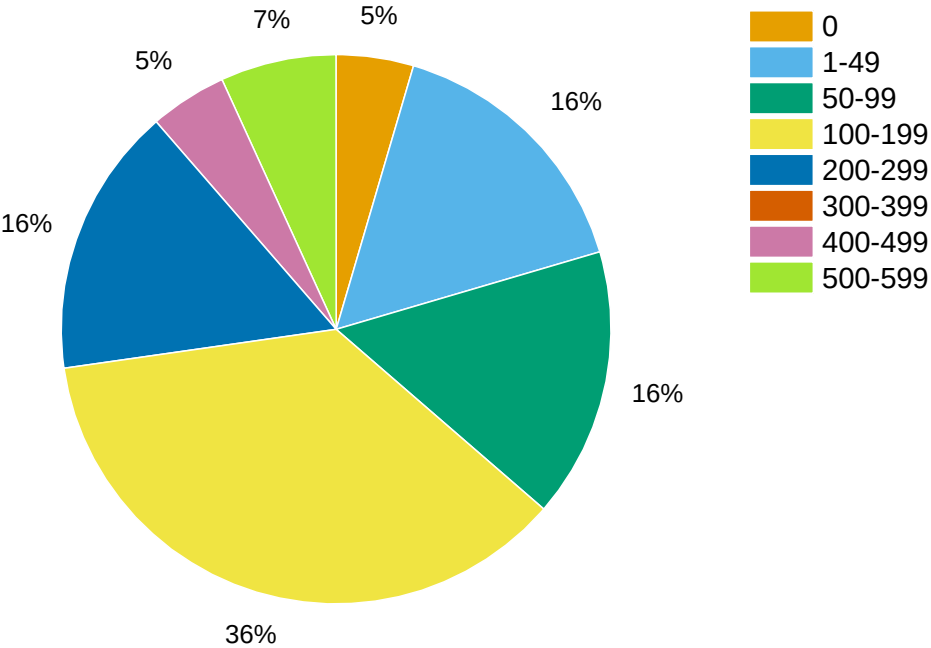


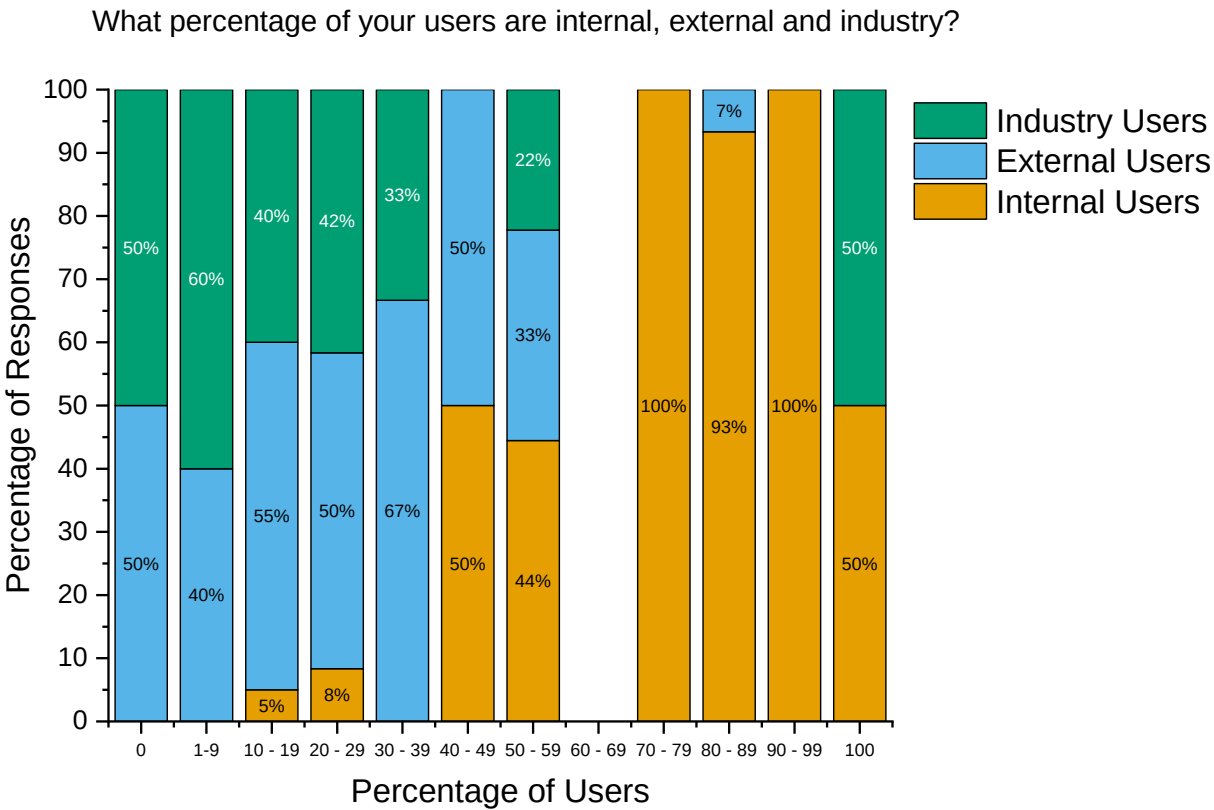
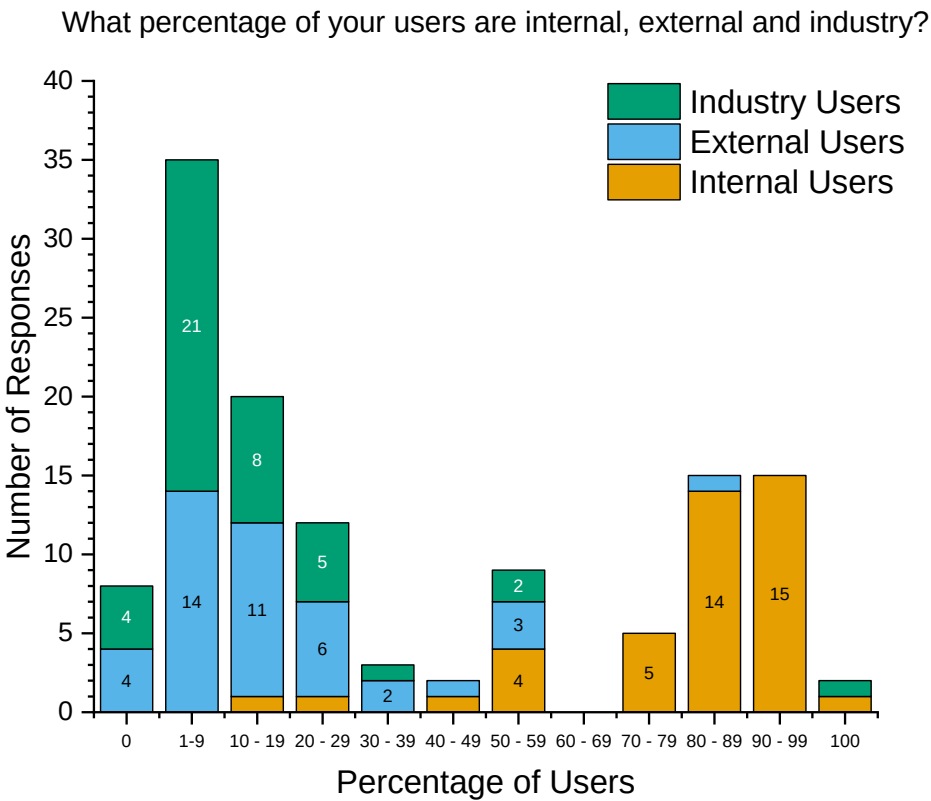
Have RTP (technical) staff been given support to attend a conference over the last 5 years?





How many users make use of your facility annually?

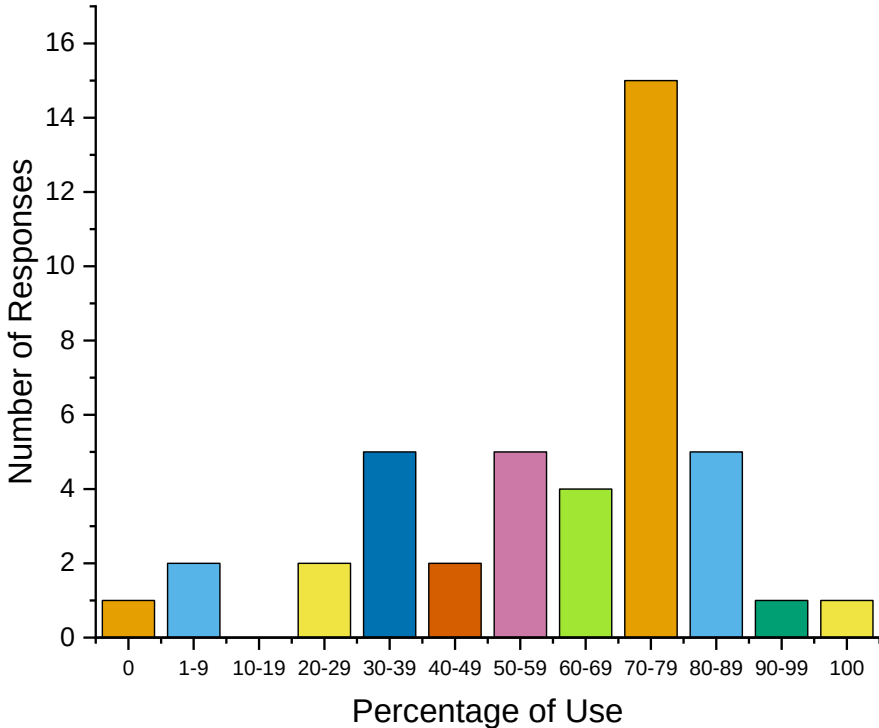




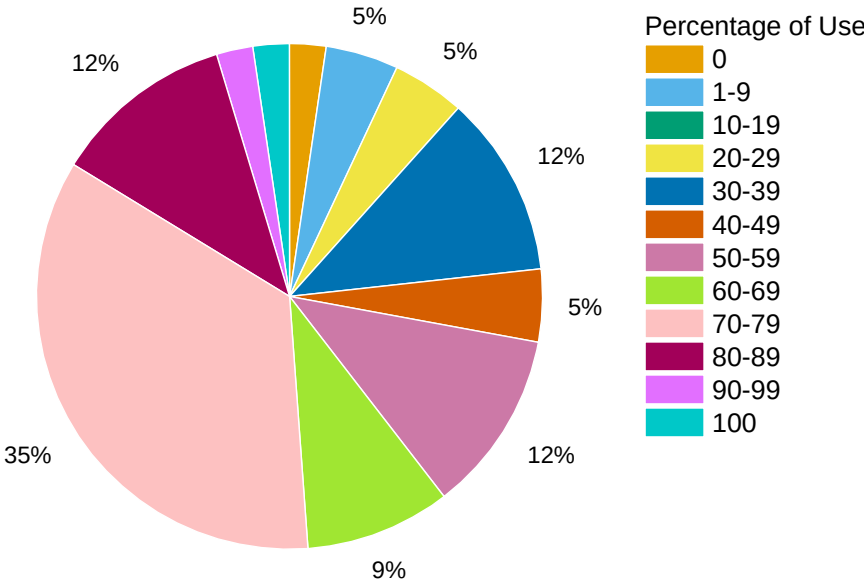
Raw number of responses

Percentage of responses

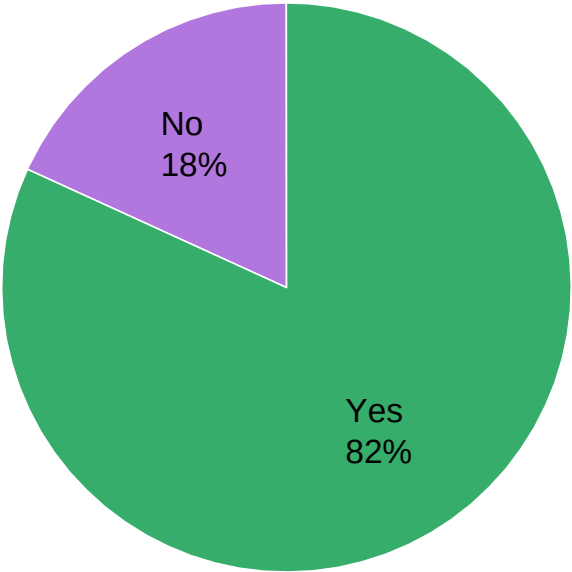
What percentage of the use of your facility is by PGT/PhD students?



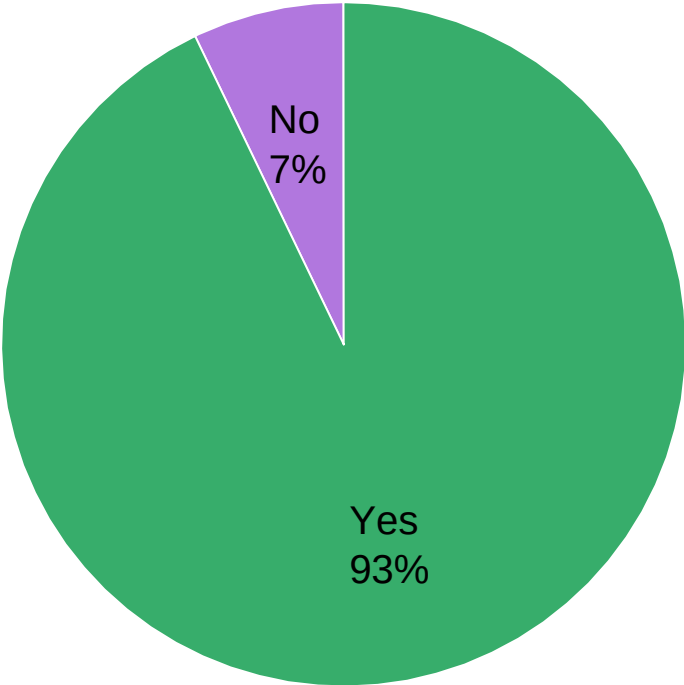
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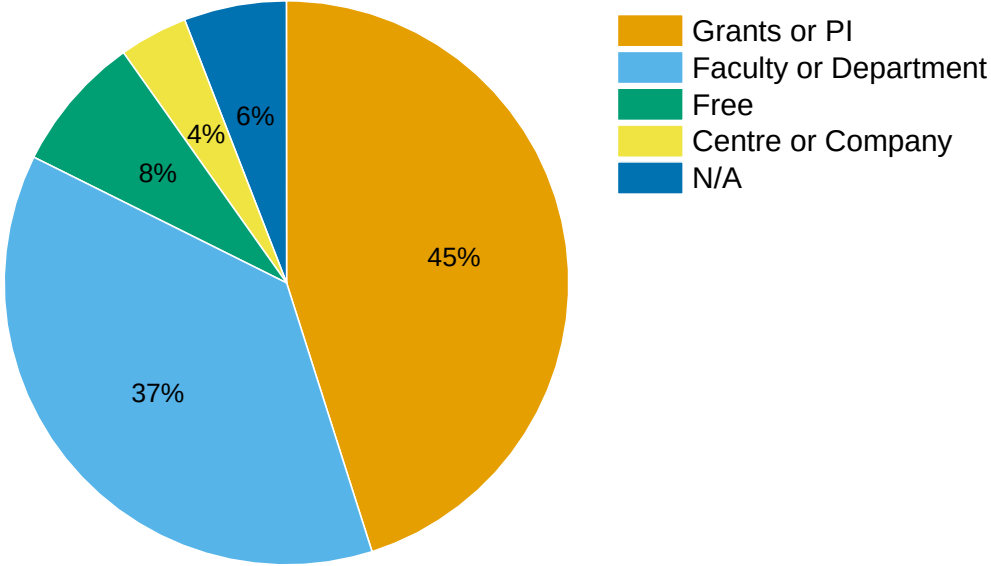
Is access to your instruments charged?



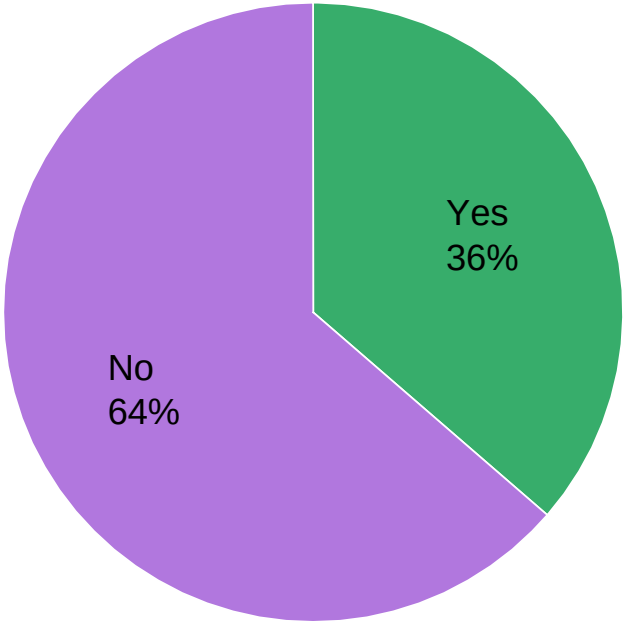
Do you have different access charges for internal and external users (including industry)?



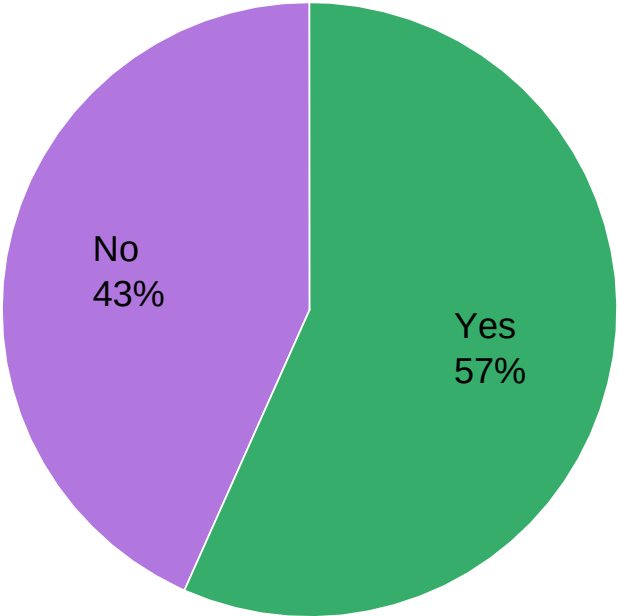
Who pays for access for PhD students (e.g. group leader, department)?



Do you have free/reduced access routes for Early Career Researchers?

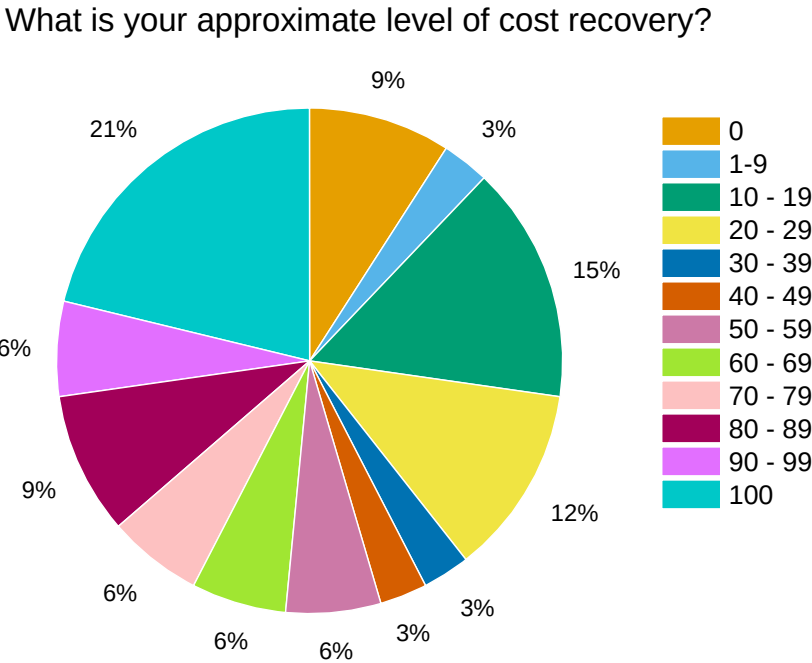
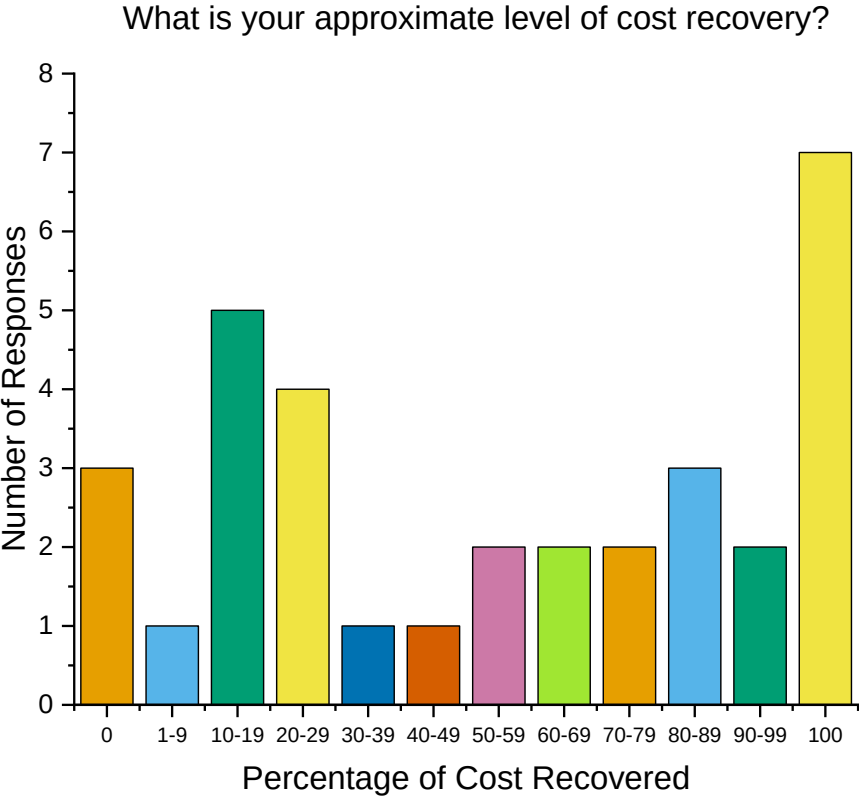


Do you try and promote Equality and Diversity for users
(e.g. preferential booking times for those with external responsibilities
or challenges etc)?

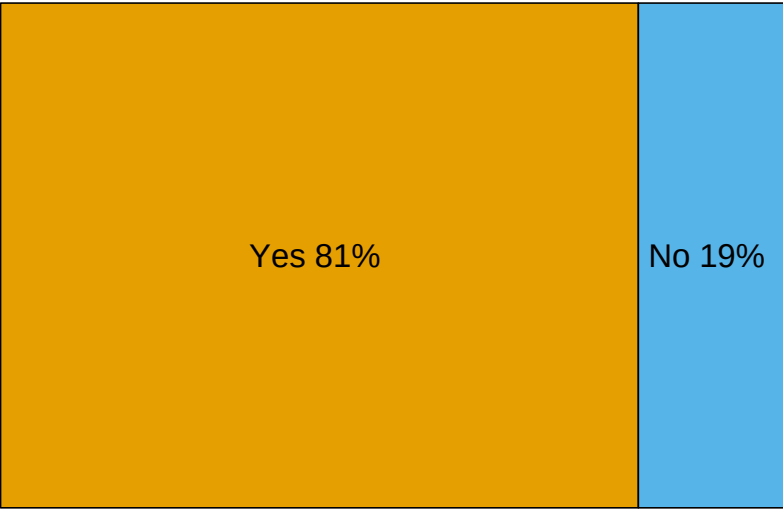


Raw number of responses

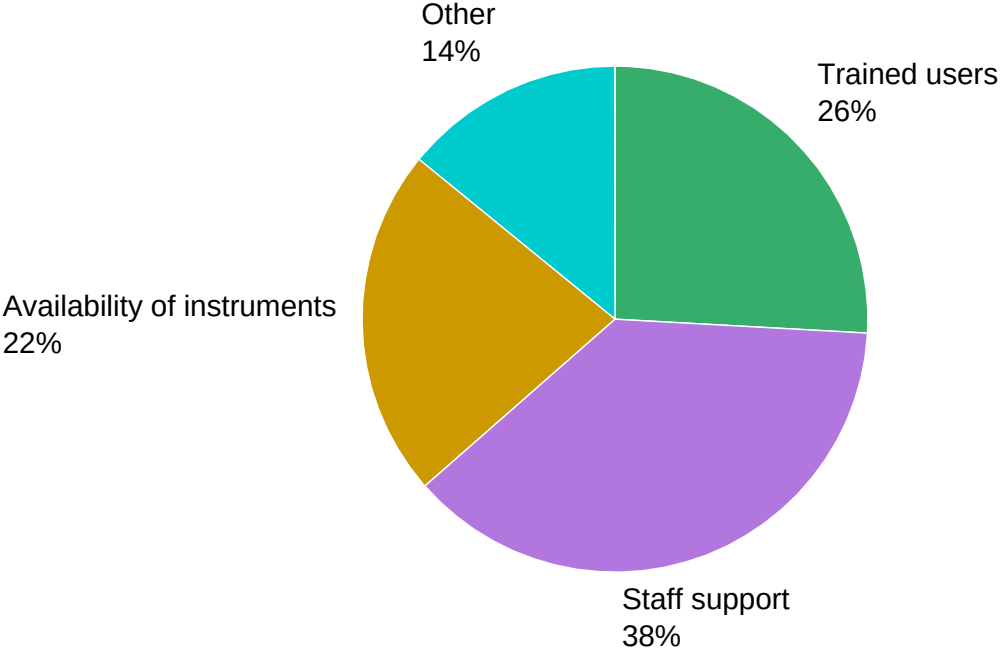
Percentage of responses



Do you support your users with data processing/data management/modelling?

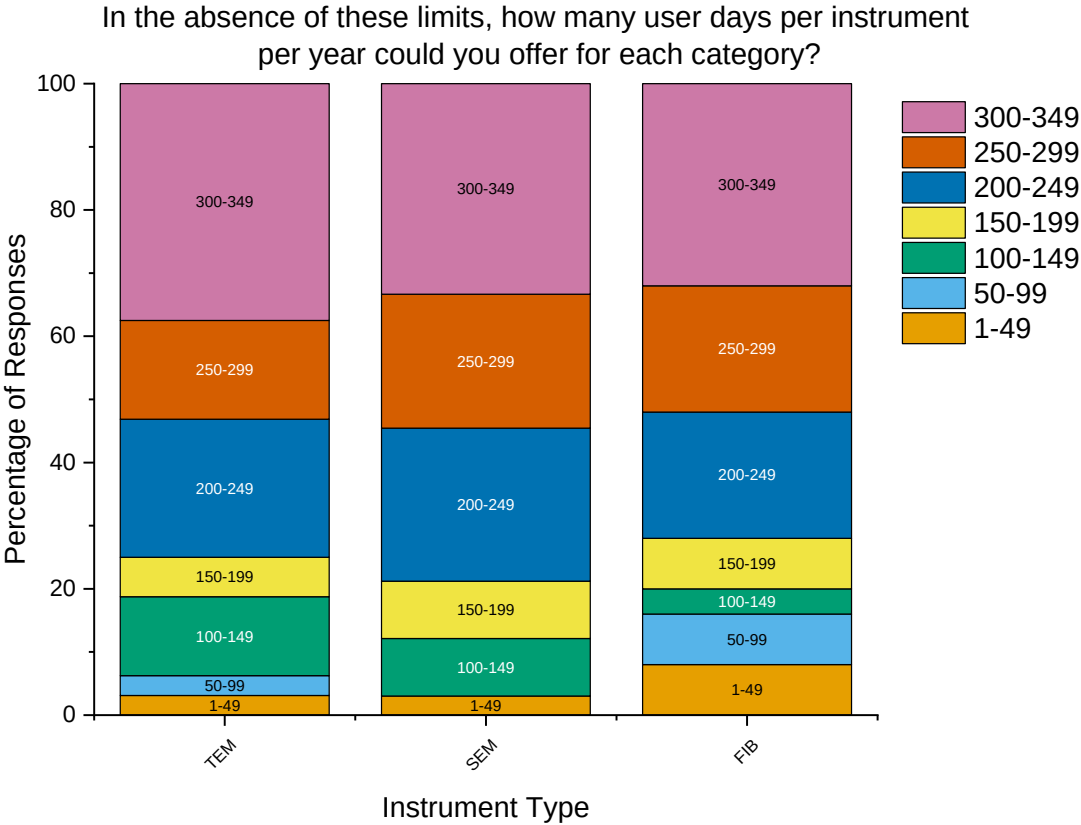
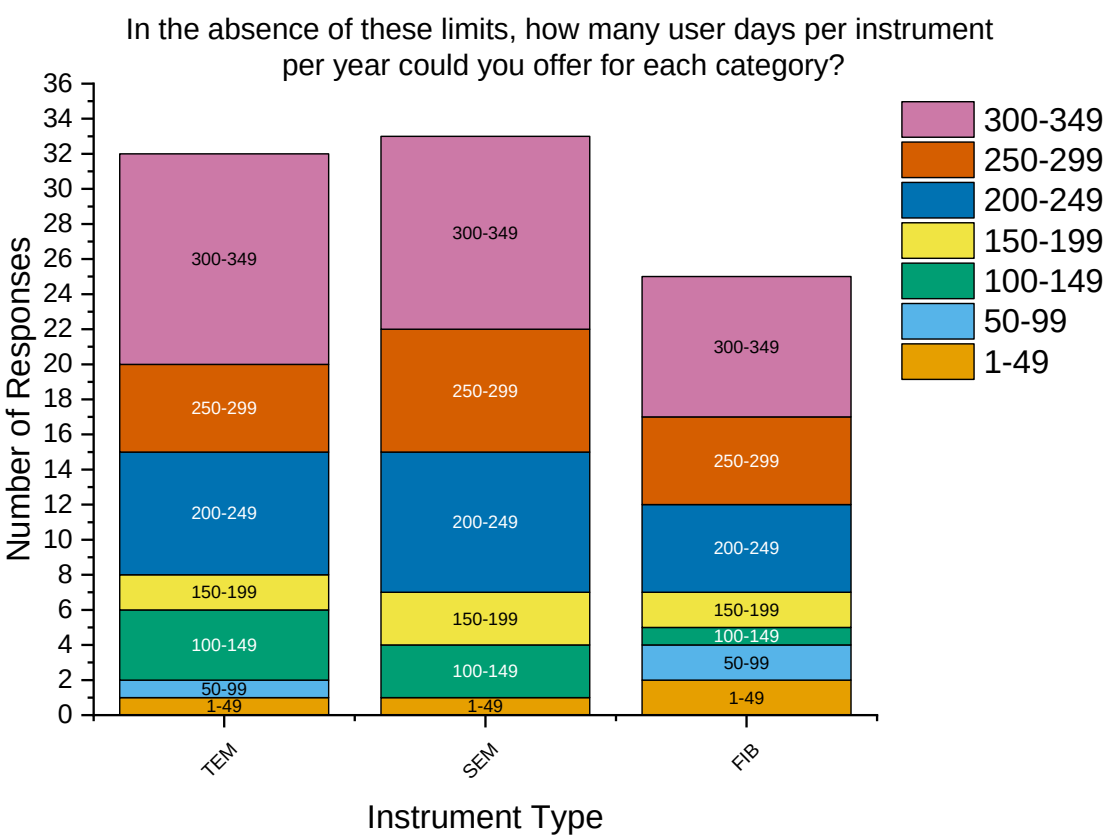


What limits the capacity of your instruments?

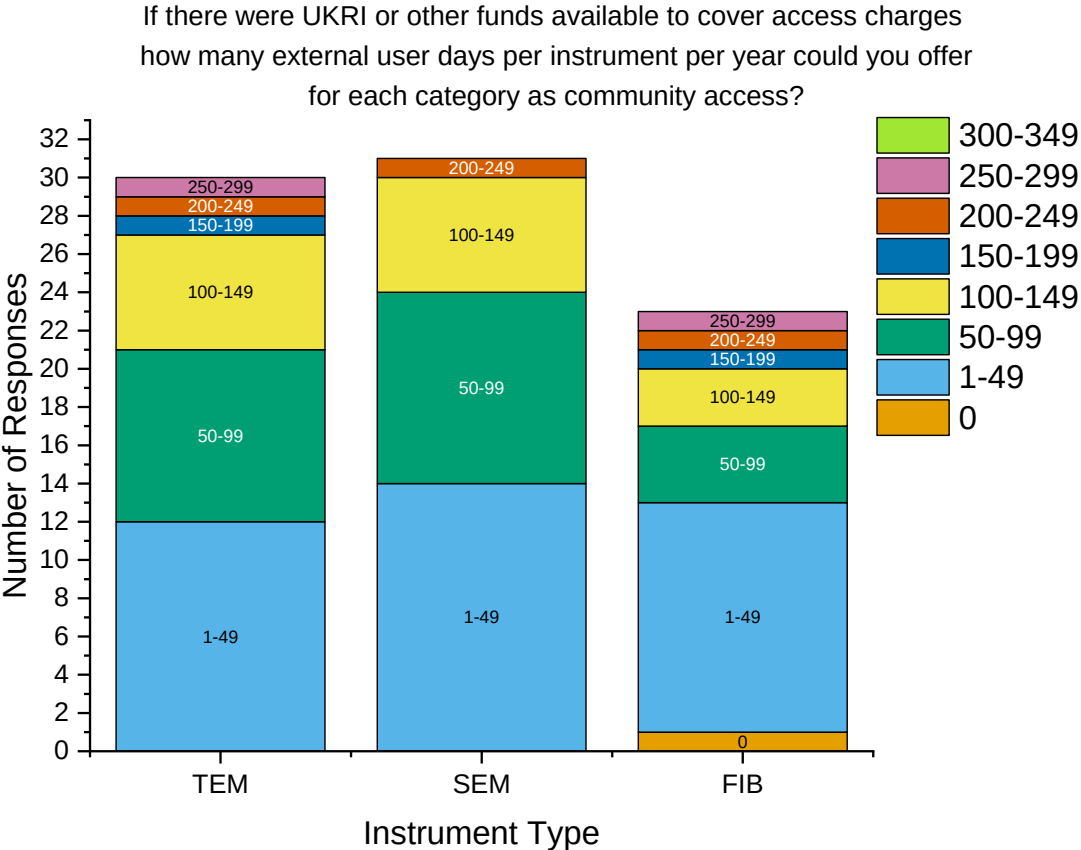


Raw number of responses

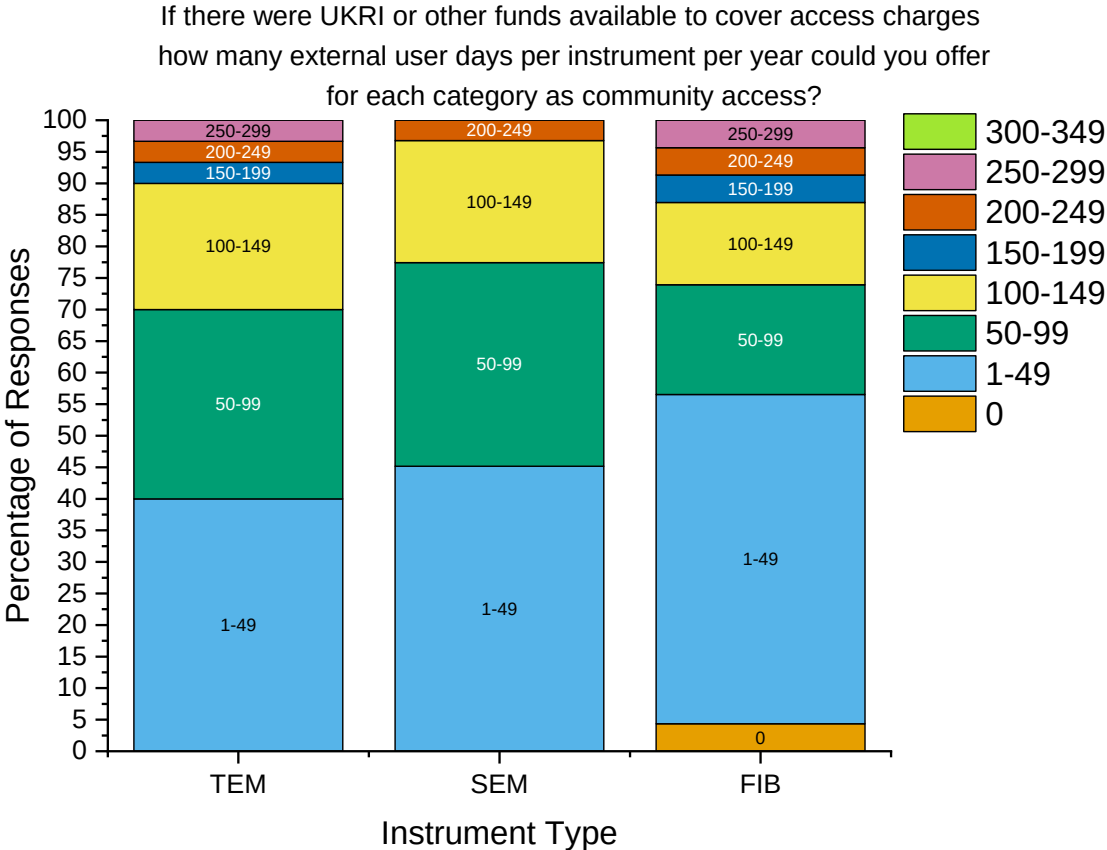
Percentage of responses



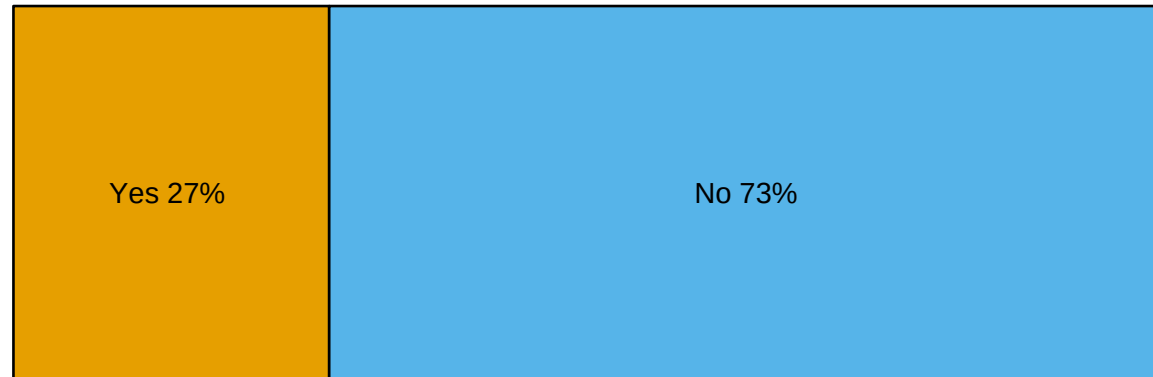
Raw number of responses



Percentage of responses



Are you part of a wider network (e.g. Royce, RFI, Faraday etc)
which could manage external access?



Q23 What role do you see for the provision of National EM facilities (or Specialist/Regional EM facilities) in the UK (e.g. in terms of techniques offered, expertise, training, access to largescale data analysis/modelling etc.)? Some answers and key quotes:

Access to analysis and modelling of large datasets

Being the resource with the capabilities and staff expertise to enable access to research and industry for specialised analytical techniques

Expertise

This seems a rational solution and could offer a long term strategy to build competence and resilience. But the model will need to include support for people, not just microscopes, as well as realistic funding for projects

EM is one of the very few areas that the UK can probably still claim as world leading and it is important that specialist facilities and expertise are well supported going forward. Of course it should also recognise the importance of training and usage of 'general users'.

High end microscopy techniques and expertise and analysis not available in our Facility

Enable access to cutting edge platforms and provision access to guidance and tools (e.g. software) that will support the national effort.

I believe national facilities should provide a central role for high end, complex experiments with devolution to regional facilities for more routine work. A more coherent network could help to facilitate this

Modelling (image simulations, electronic structures, EELS)

Environmental TEM/STEM and diffraction

Free or nominal charges for students. Provide free training, organise seminars etc.

It would be nice to have a central hub to find out system information, but also to receive free consultation on your project.

We would like to see more connection with smaller facilities by the large high-end facilities to share best practice and capability.

National facilities are important to offer and push forward advanced techniques (e.g. ultra low-loss EELS at SuperSTEM or ptychography at ePSIC). They also act as great training hubs for techniques and processing.

In terms of techniques offered, local SEM, FIB and TEM facilities should be encouraged and maintained at each university. Each centre can then tailor their facilities for the research focus of the host university.

National facilities should offer state of the art techniques which require hardware / expertise / resource not generally available in universities. They should encourage and support access to instrumentation from the widest range of users, fully supporting those with little or no EM experience. Finally they should provide a resource for training students and postdocs in state of the art EM experimental and analysis techniques.

What EM capabilities are currently missing from the UK portfolio?

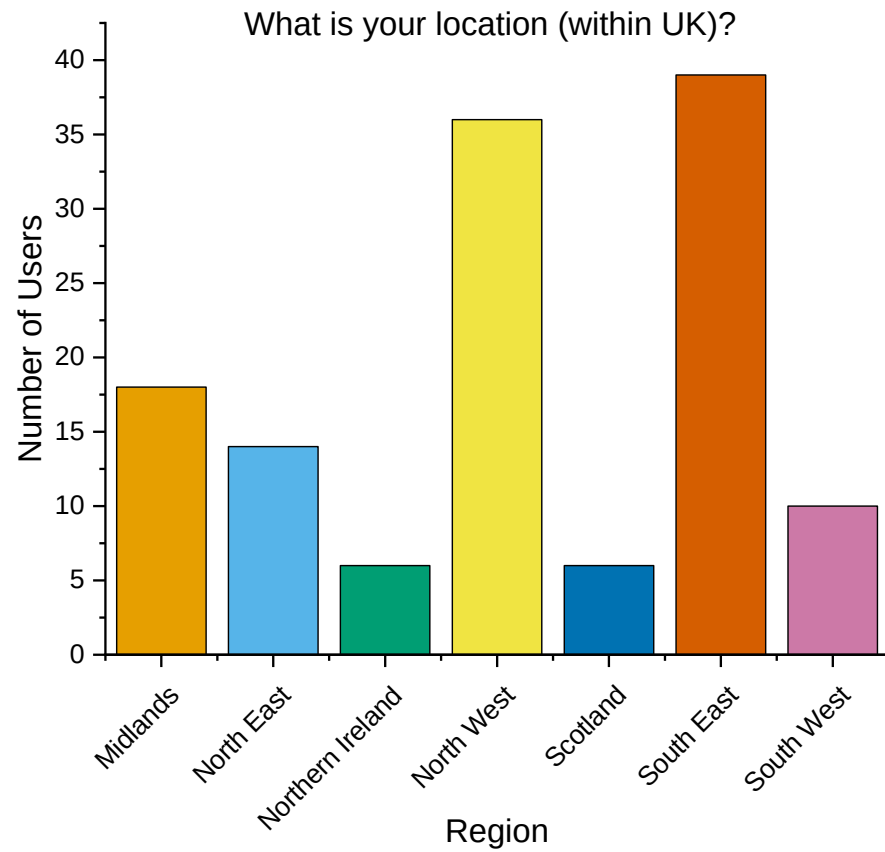
Some answers and key quotes:

- Electron diffraction
- ETEM / ESTEM
- Locally micro-XRF, TOF SIMS
- Dedicated FIB-SEM for atom probe preparation
- Training and support for automated control and analysis.
- Greater national support for training in optimised sample preparation (beyond FIB).
- Time-resolved electron microscopy at all energies
- High voltage TEM for in-situ studies and irradiation damage
- Chemical analysis and in-situ capability for radioactive materials
- In-situ (in operando) EM (e.g. variable B field and biasing, stress-strain etc.)
- High quality specimen prep
- Correlative microscopies (light + electrons, e.g. for low energy EELS)
- Dynamical studies in vacuum and in realistic conditions
- EM of beam sensitive materials
- AI based approach on large data sets
- Most techniques are in the portfolio but access to them is very mixed.
- A high resolution field free EM (though maybe this in on the roadmap for superSTEM).
- High-resolution EELS mapping, 4D STEM
- Corrected STEM with cryo capability
- I am not aware of any EM capabilities that the UK is missing.
- Not sure...but we are missing staff to run microscopes competently and analyse data to extract all available info
- Fast scanning capabilities, low temperature (He) sample stages, variable field TEM/STEM capabilities
- I perceive a general lack of capacity in routine EM facilities, this seems to be keeping the cost of access barrier high, especially routine FIB access.
- Specialised electrochemical in situ (S)TEM
- Dedicated ultra-low temperature, high spatial and energy resolution instrument, as supported in a recent statement of need from the community.
- Access to expertise in non-destructive imaging and analysis for cultural heritage research
- Ultrafast, imaging and diffraction, separate instruments.
- More online resources for data analysis, modelling etc would all be welcomed.
- Lorenz Aberration corrected imaging at cryo temperatures, probably situated at Super STEM.
- Laser pump probe both at national facilities

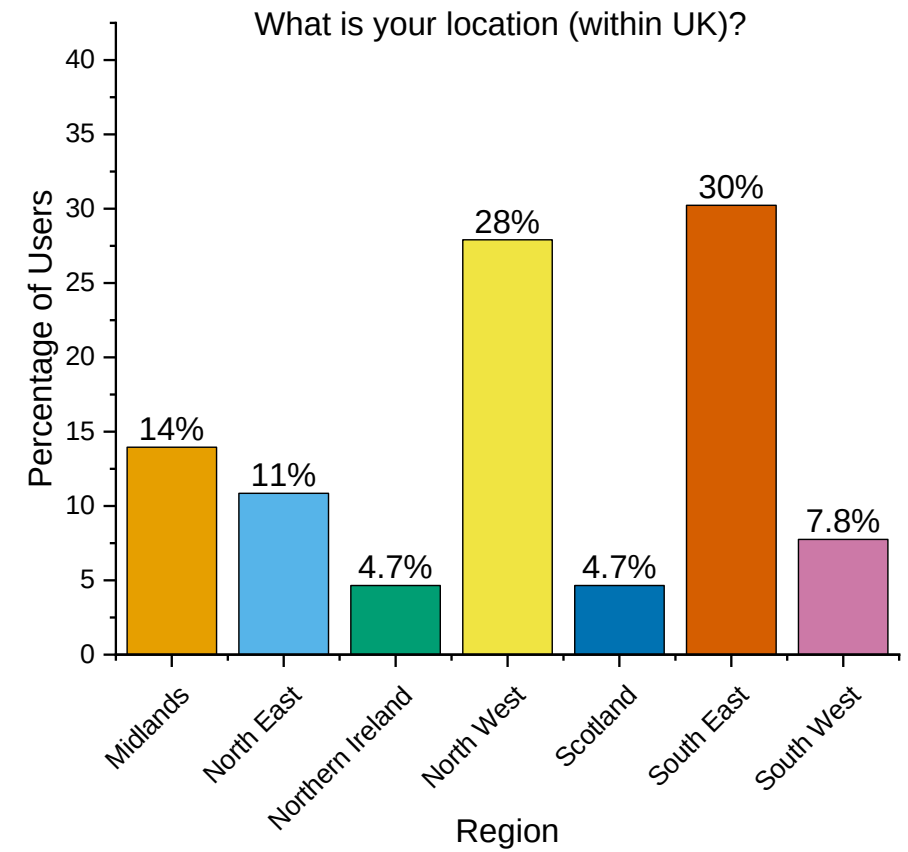
EM User Survey

(15 questions) - **129** responses

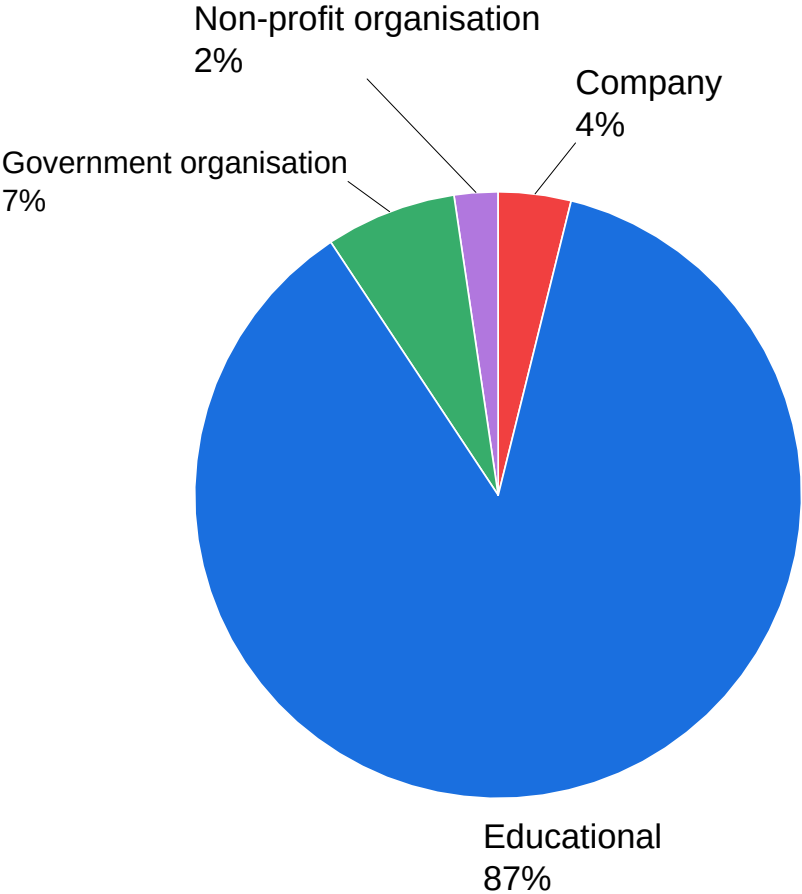
Raw number of responses



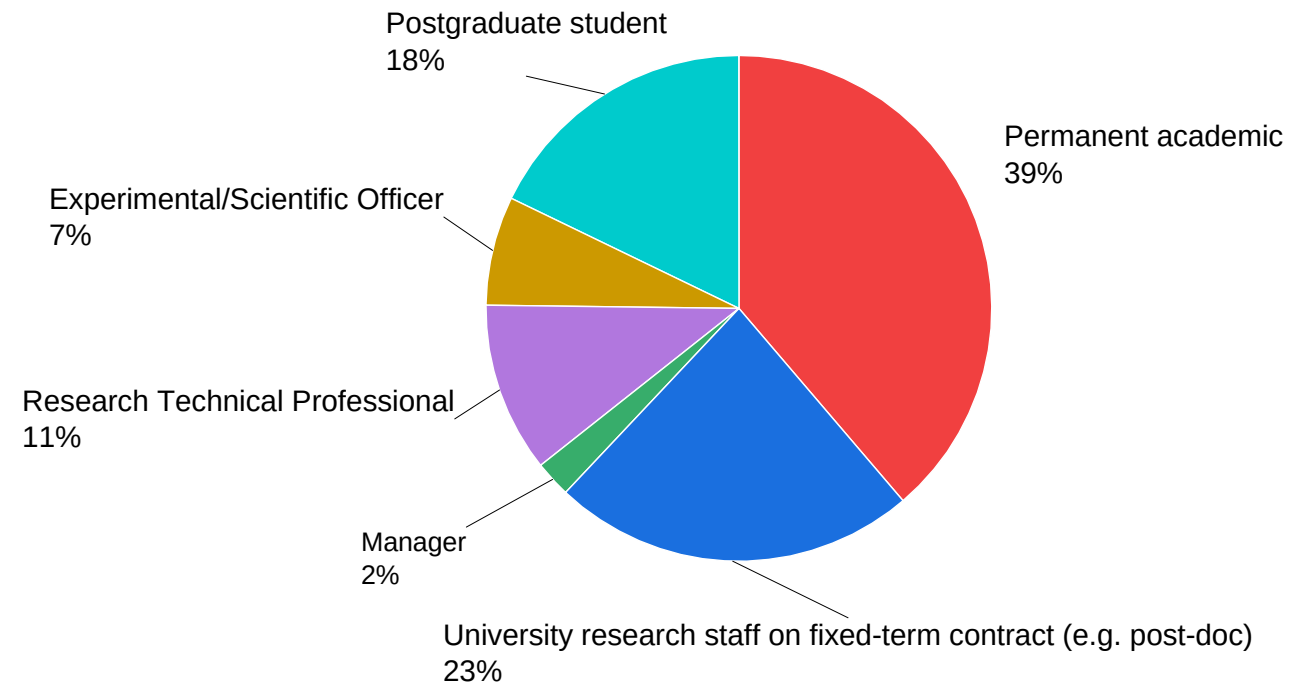
Percentage of responses



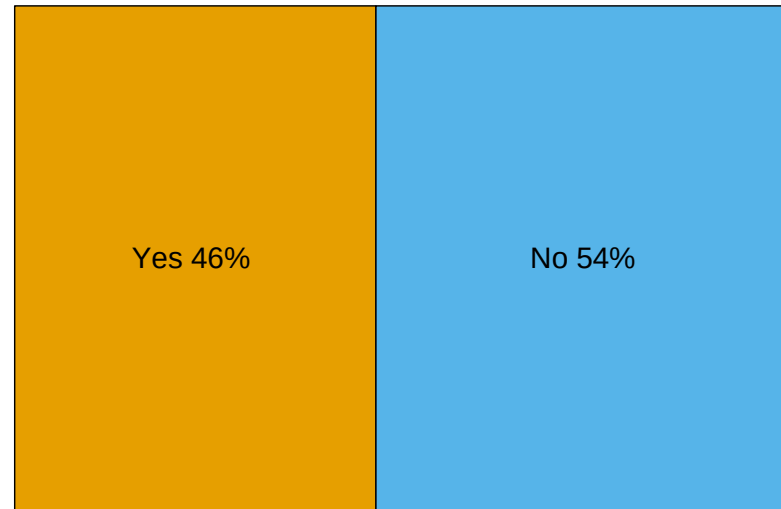
Which of the following best describes your organisation?



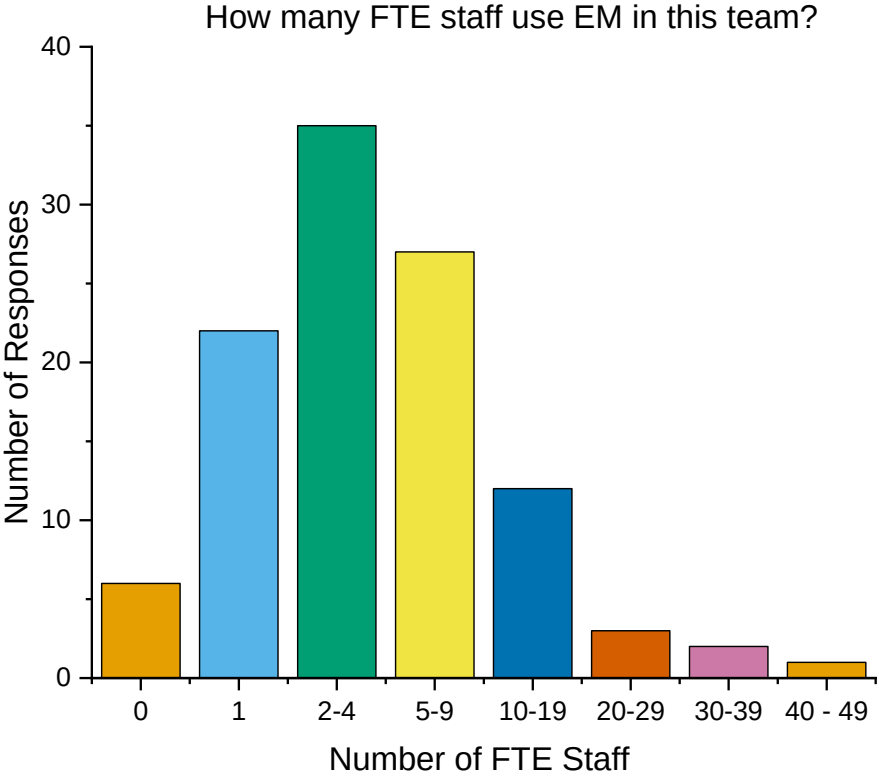
Which of the following best describes your professional position?



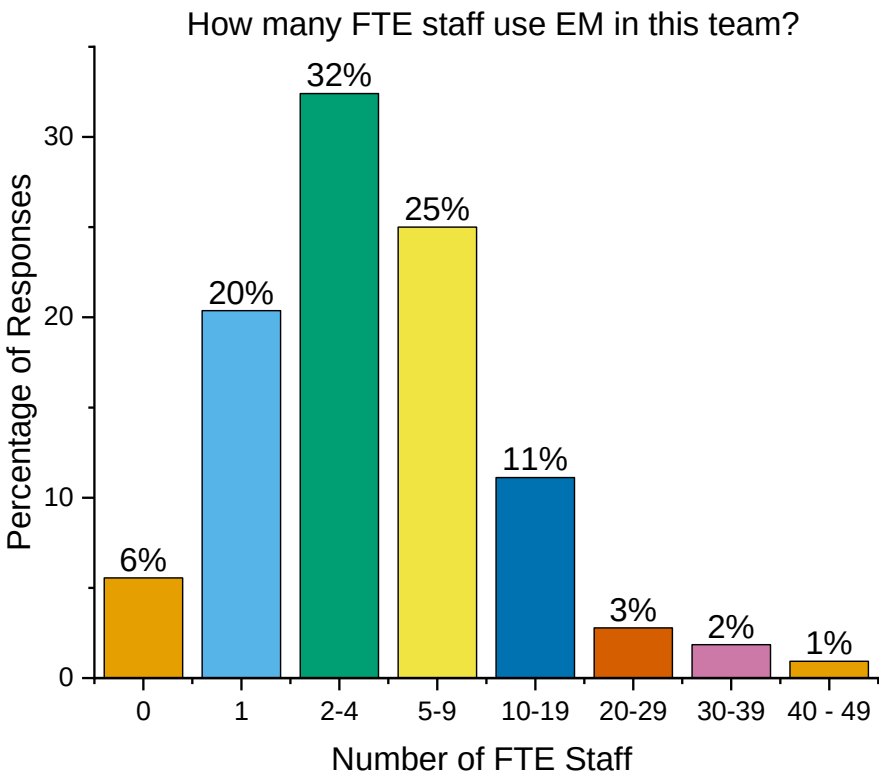
Do you supervise or lead a team which uses EM?



Raw number of responses

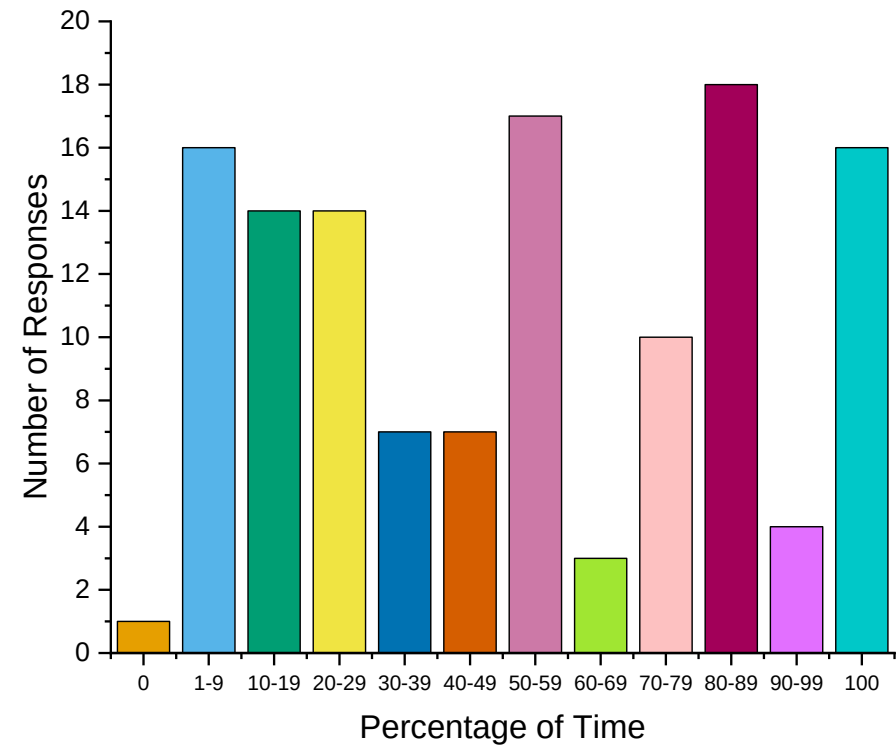


Percentage of responses



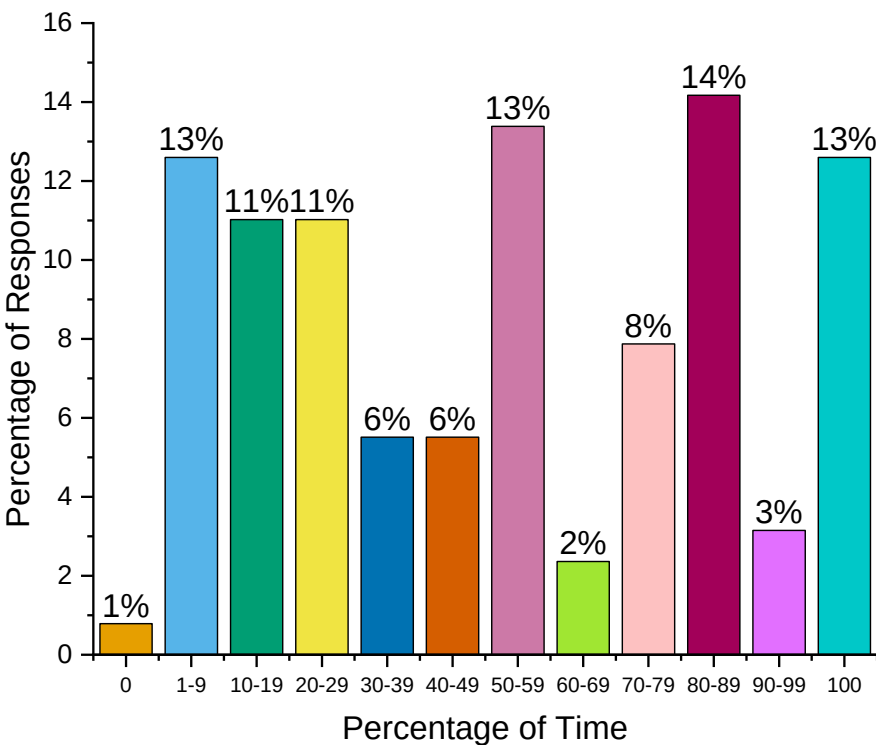
Raw number of responses

What percentage of your/the teams time is spent on EM and EM-related work?

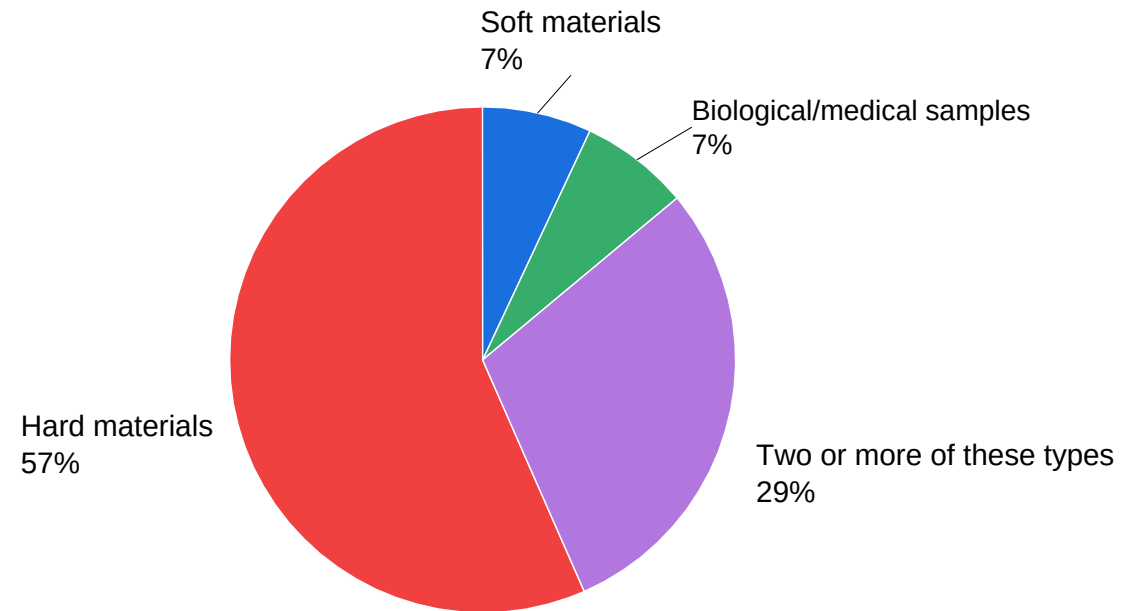


Percentage of responses

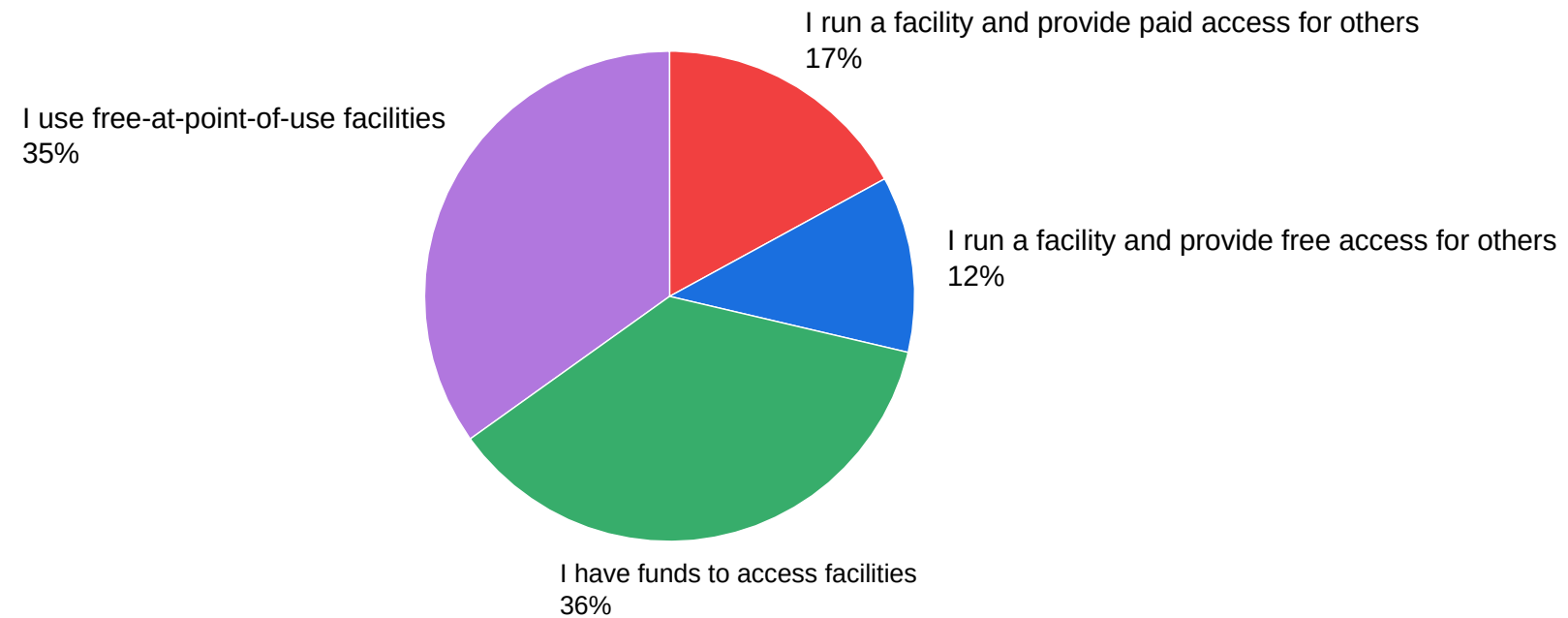
What percentage of your/the teams time is spent on EM and EM-related work?



What kind of samples are you mainly interested in?



For your EM work, do you have funding to pay an instrument access charge or do you use free-at-point-of-use facilities?

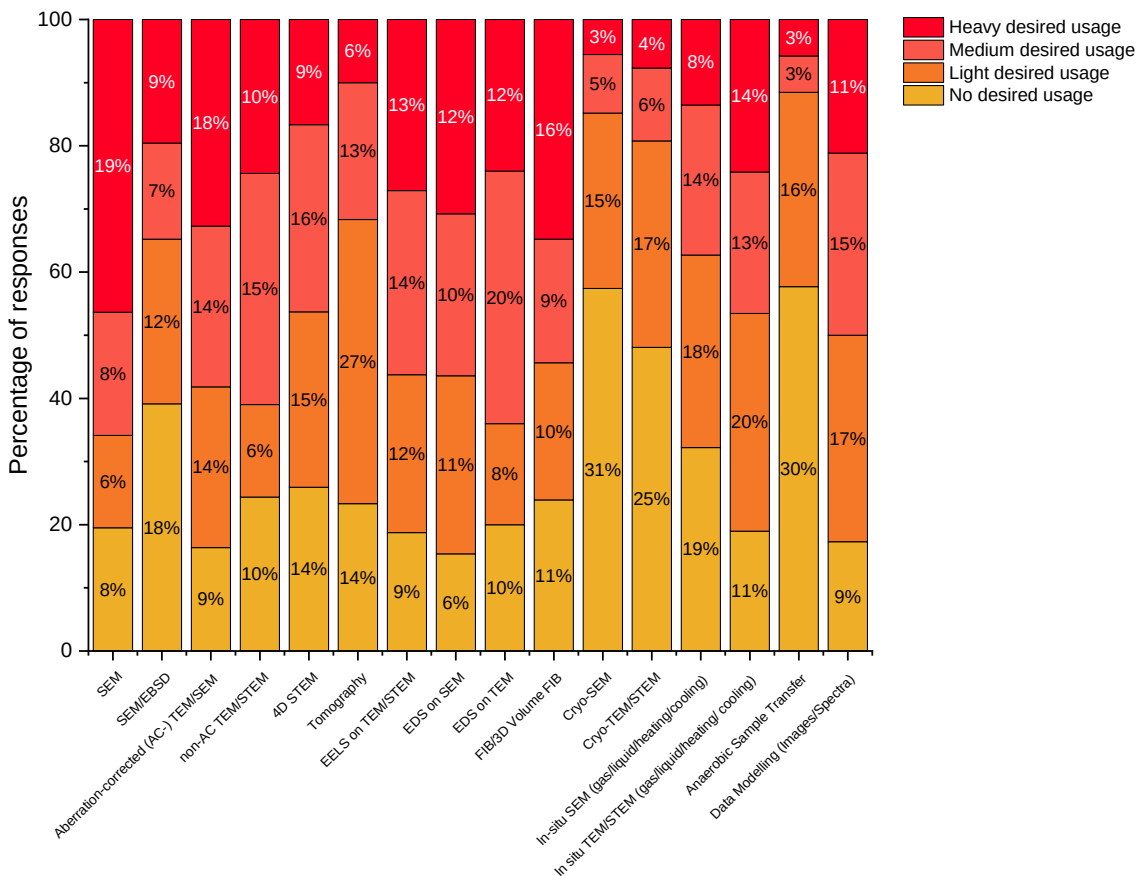
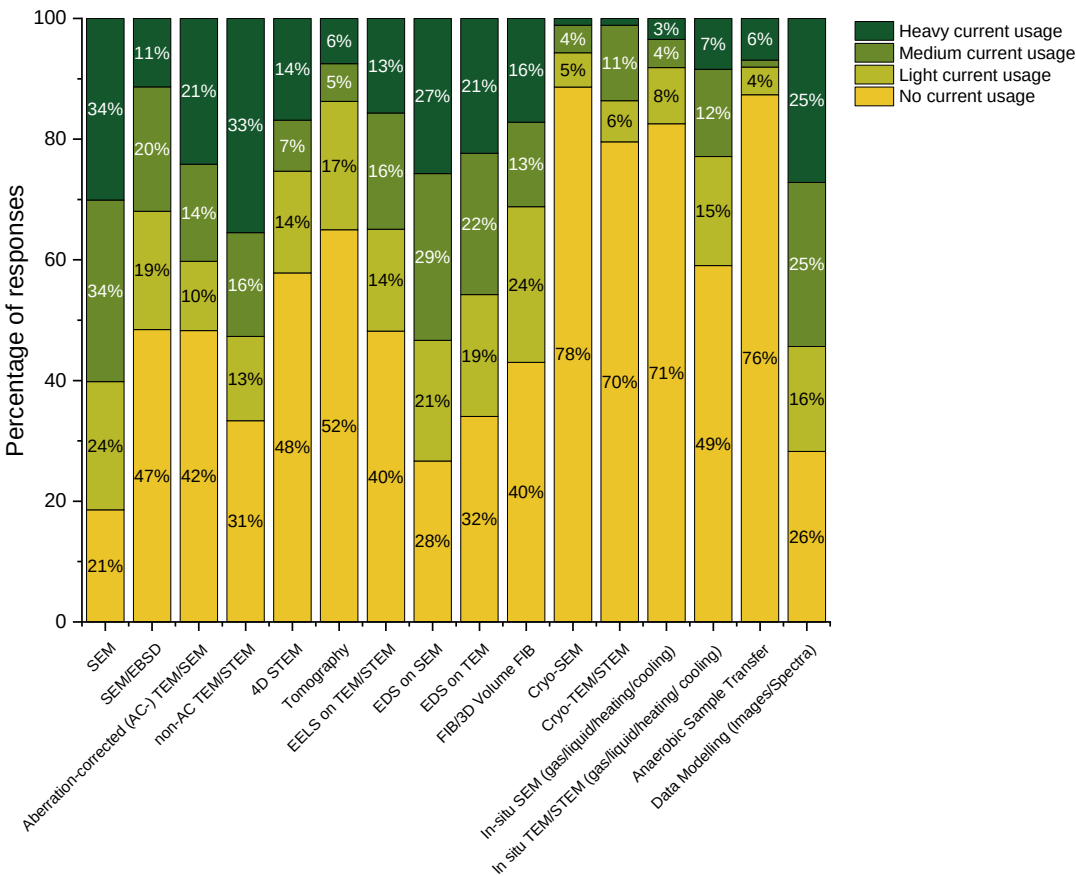


Current Usage

Desired Usage

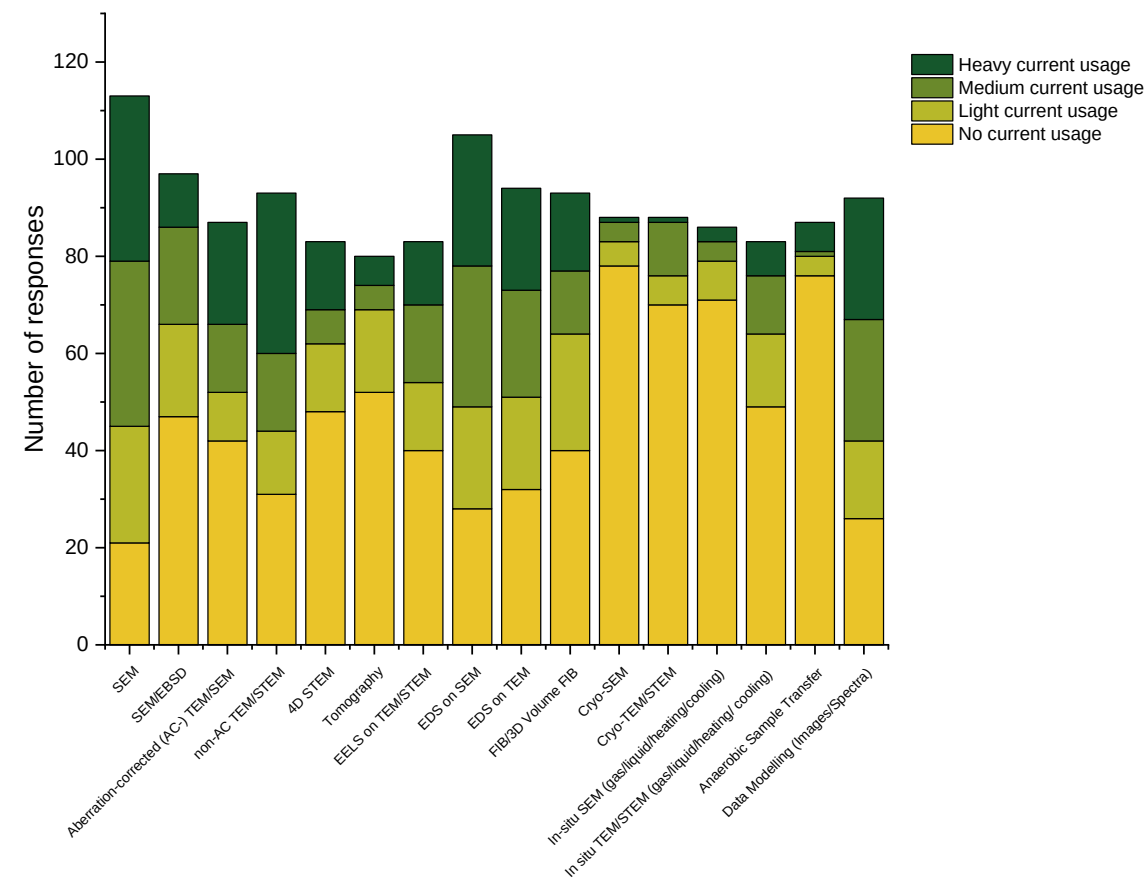
Describe your current usage of these techniques and whether you would like to use them
(Light < 5 days per year; Heavy > 40 days per year)

Describe your current usage of these techniques and whether you would like to use them
(Light < 5 days per year; Heavy > 40 days per year)



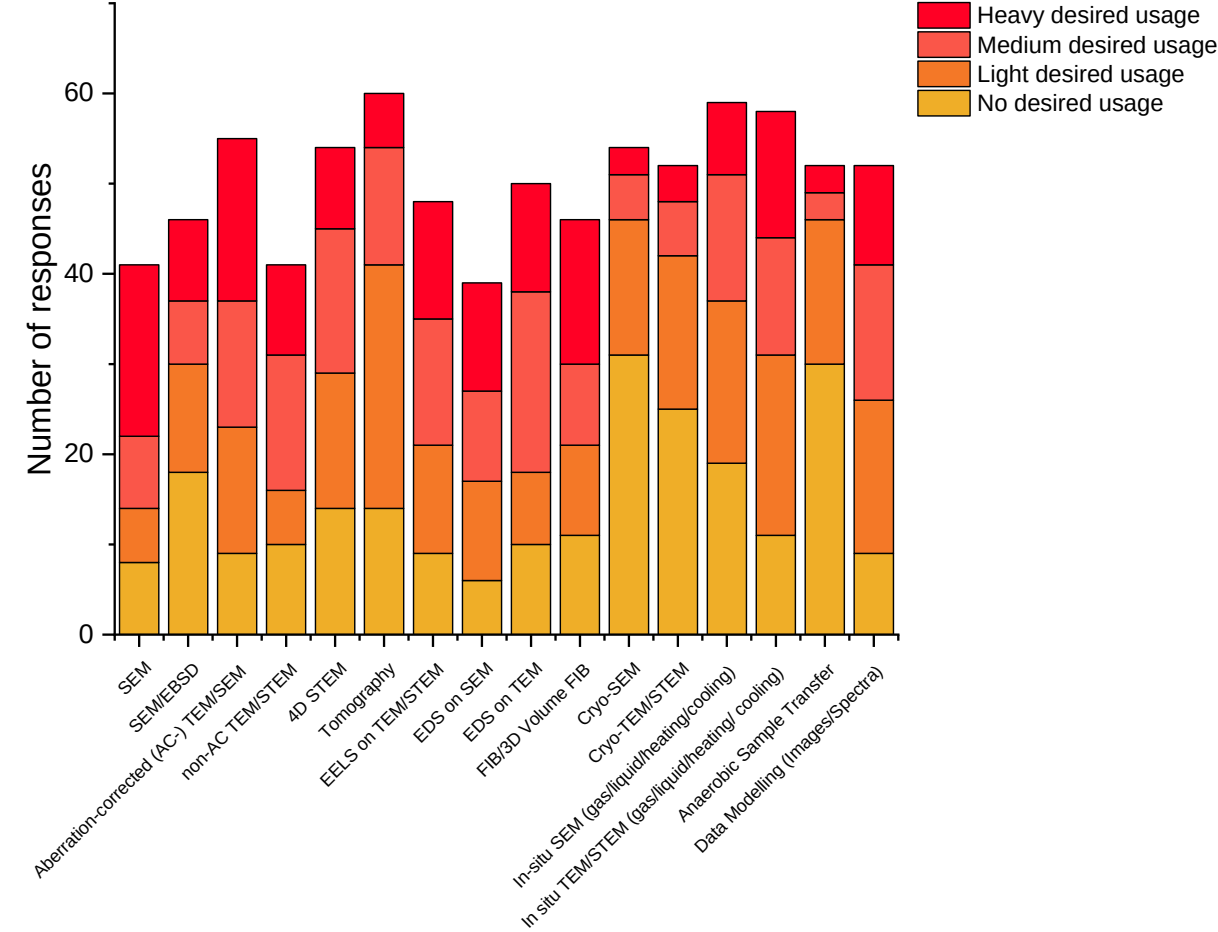
Current Usage

Describe your current usage of these techniques and whether you would like to use them
(Light < 5 days per year; Heavy > 40 days per year)

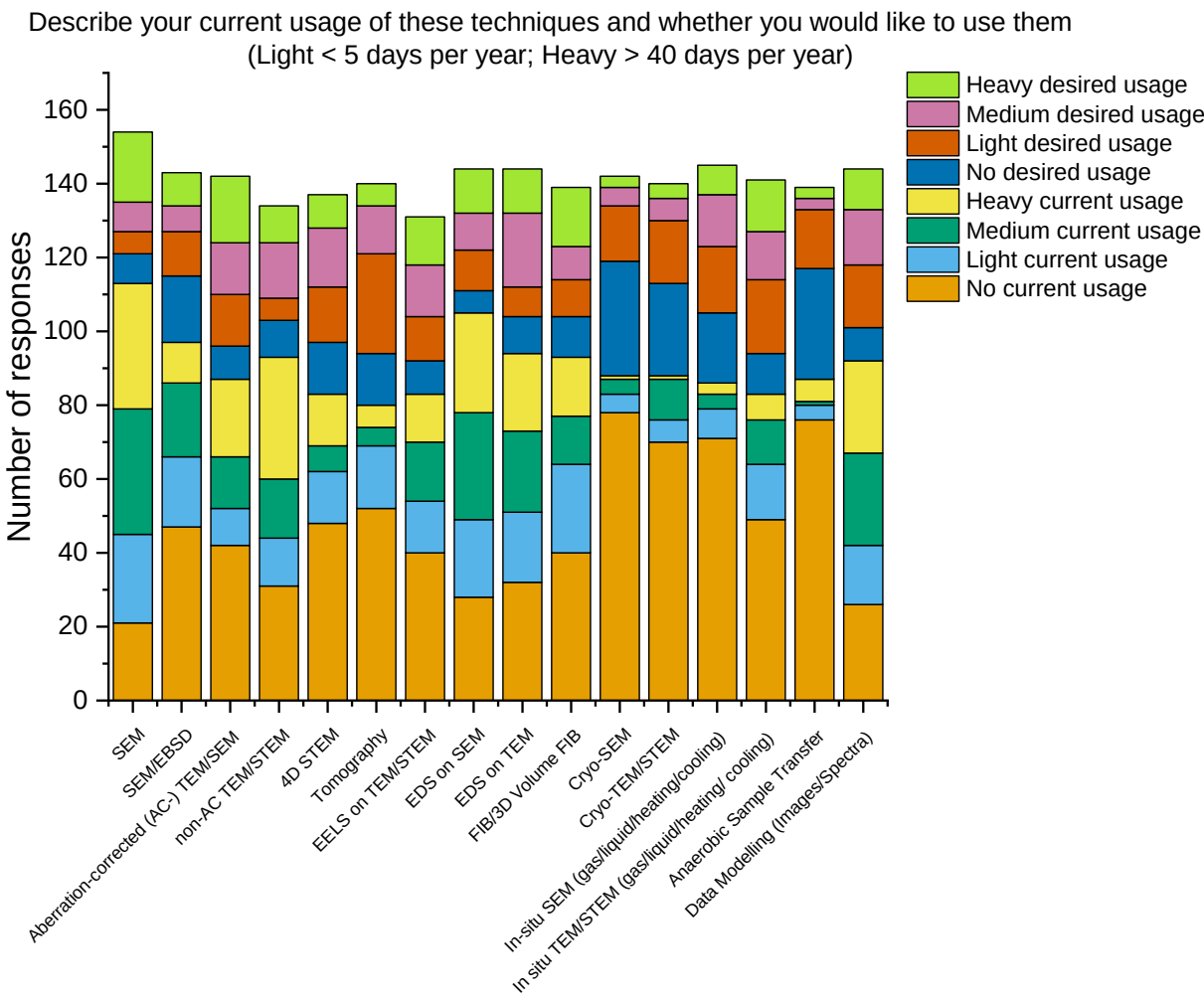


Desired Usage

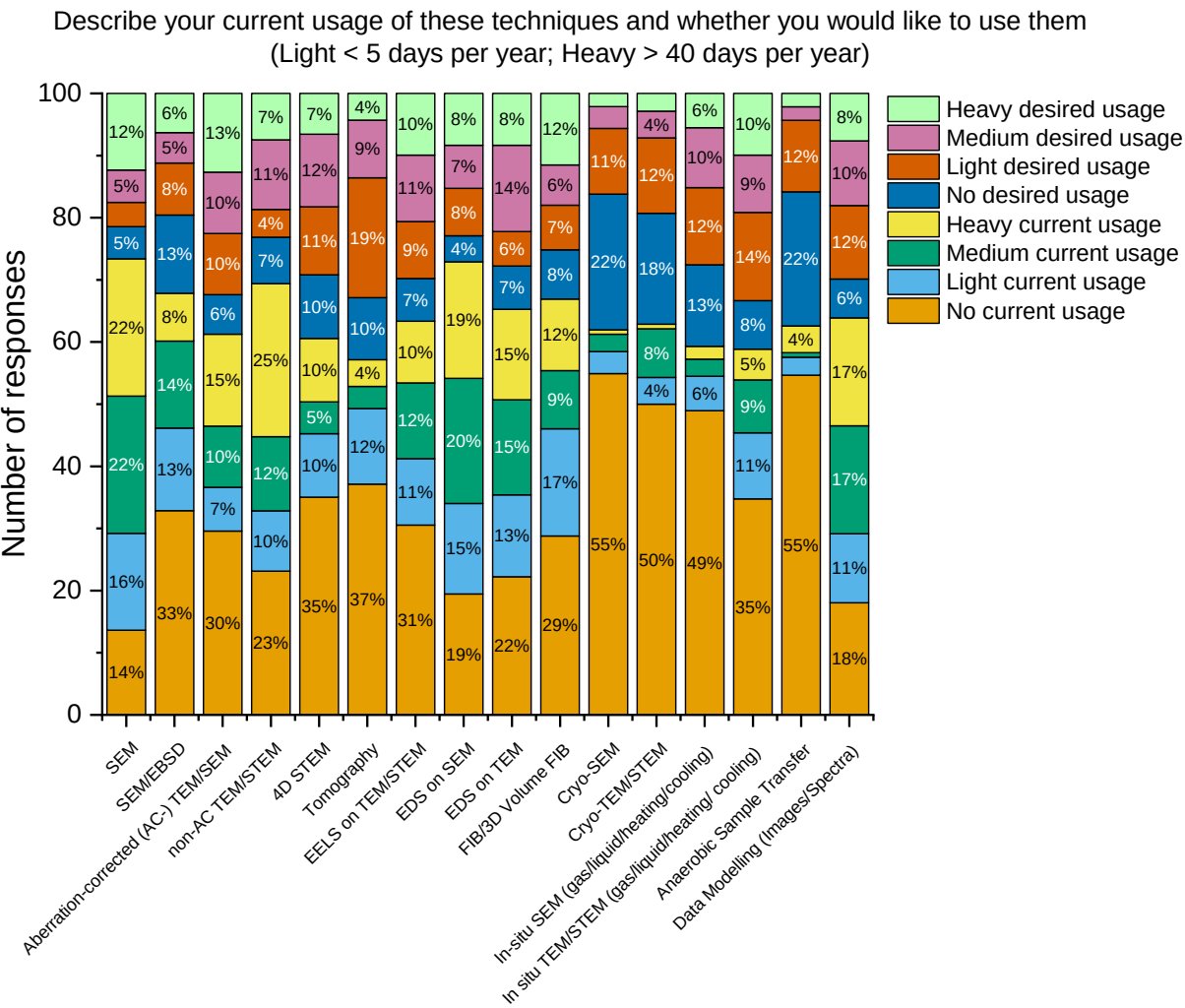
Describe your current usage of these techniques and whether you would like to use them
(Light < 5 days per year; Heavy > 40 days per year)



Raw number of responses

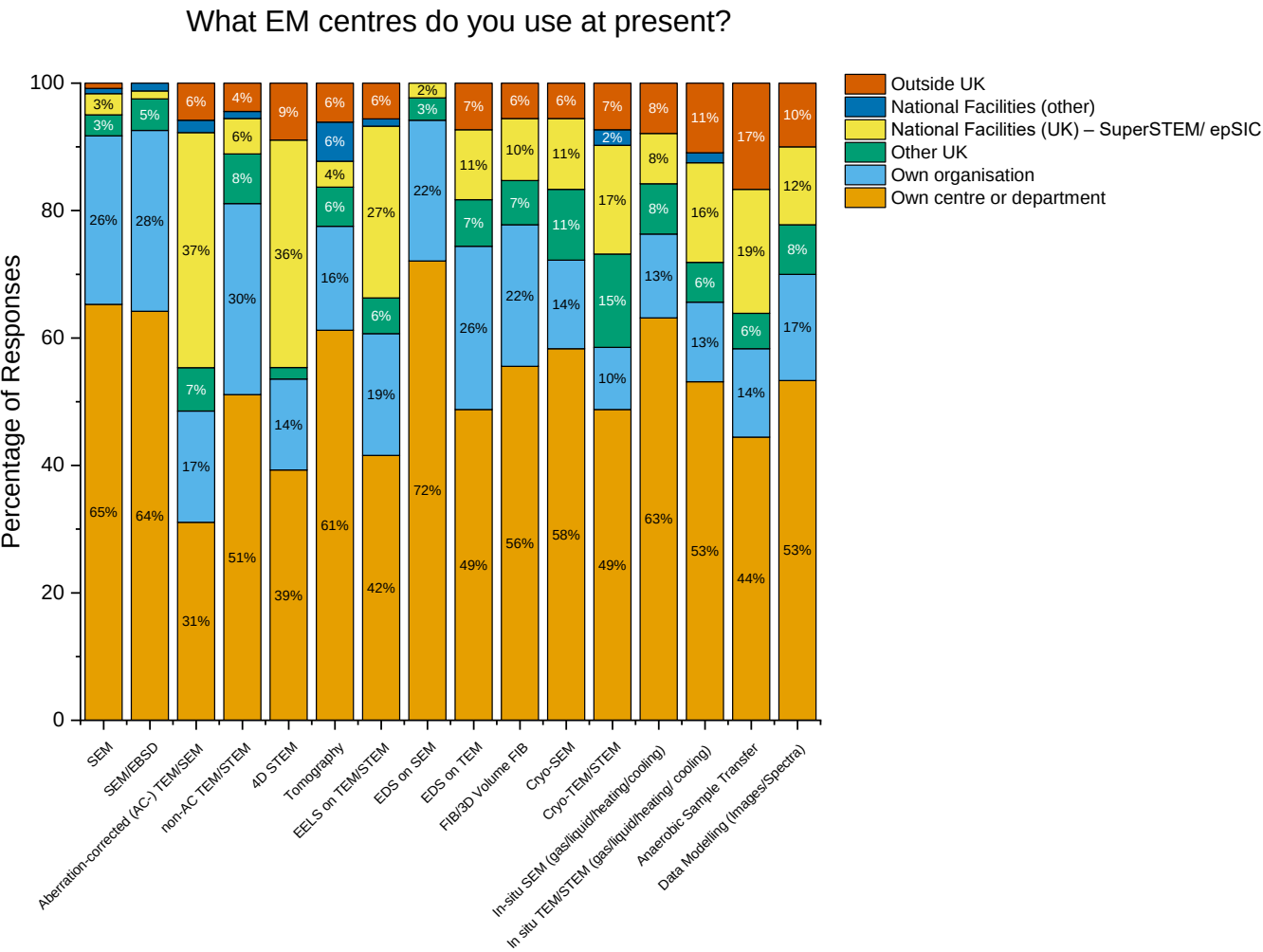


Percentage of responses

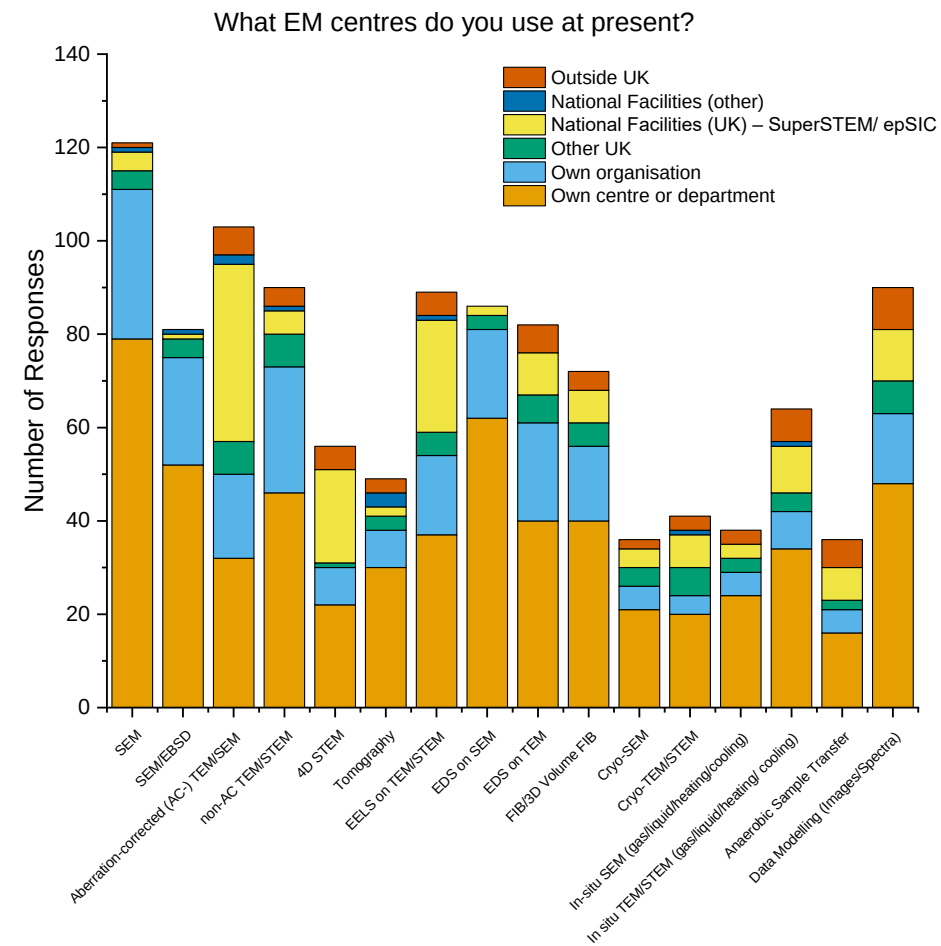


Q10

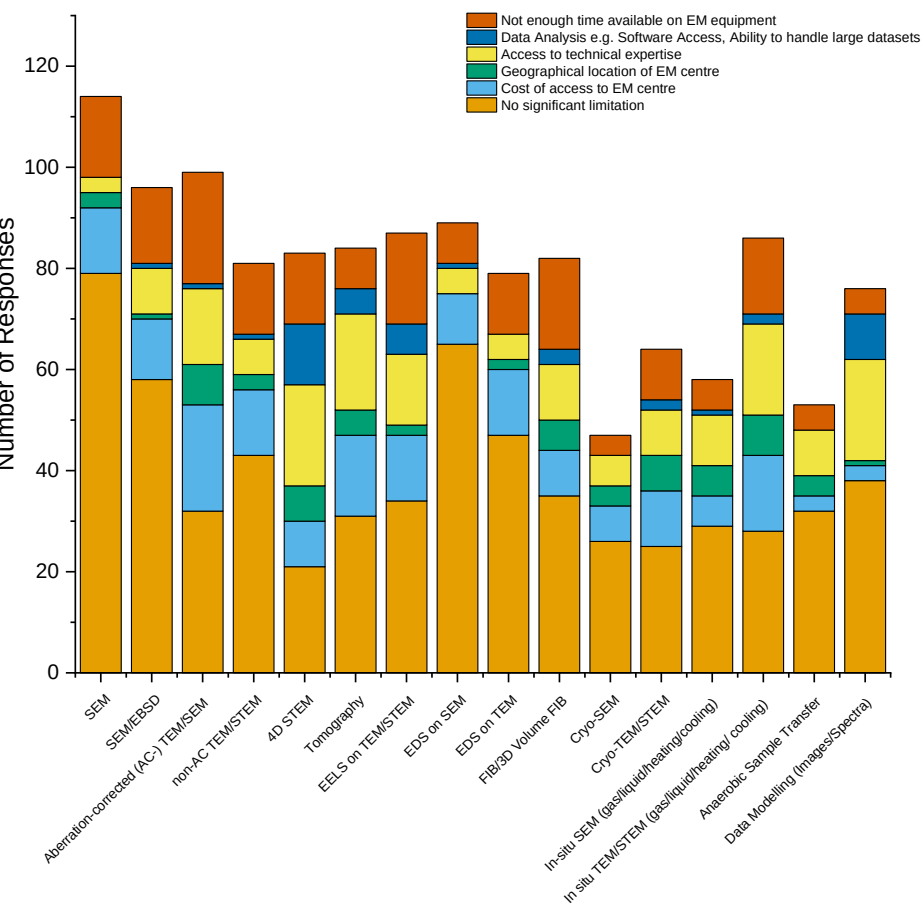
Raw number of responses



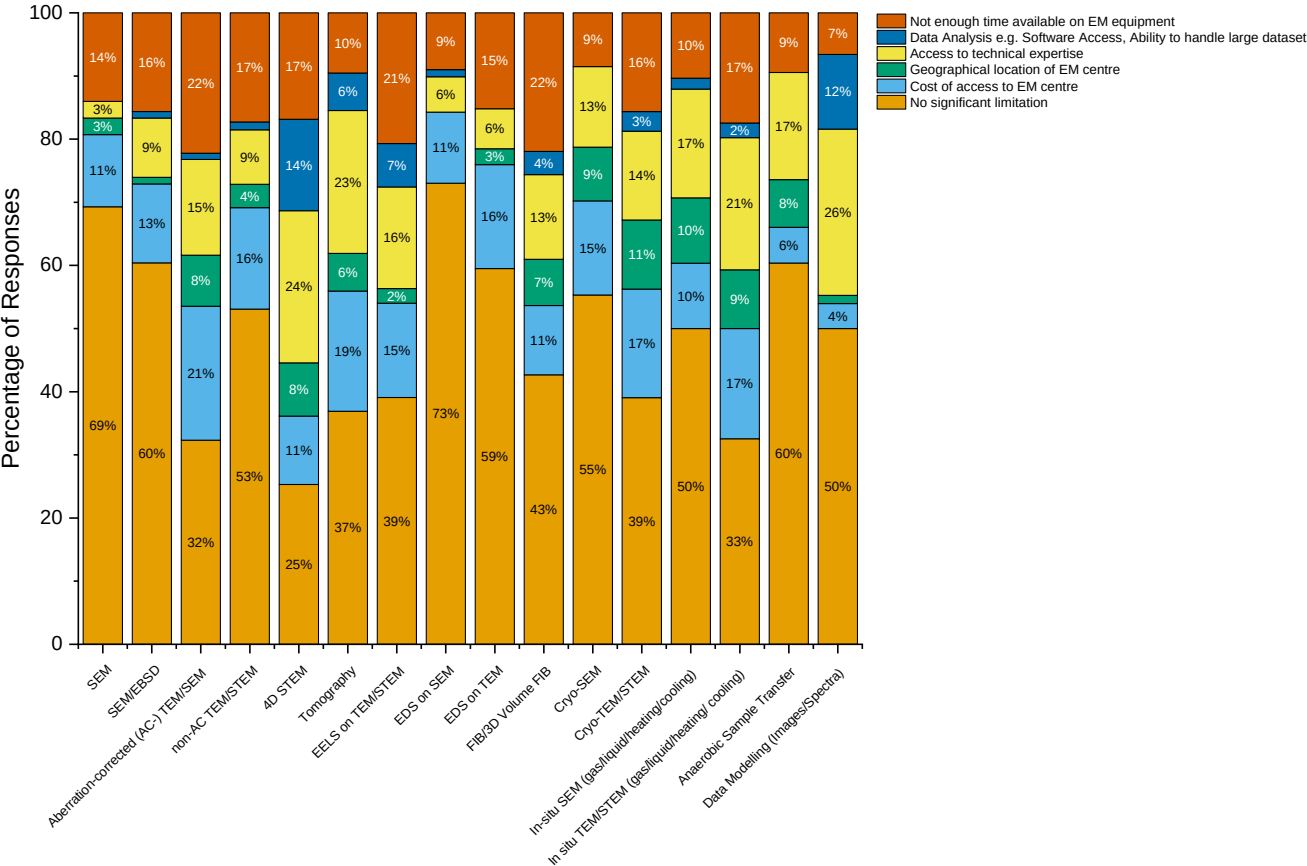
Percentage of responses



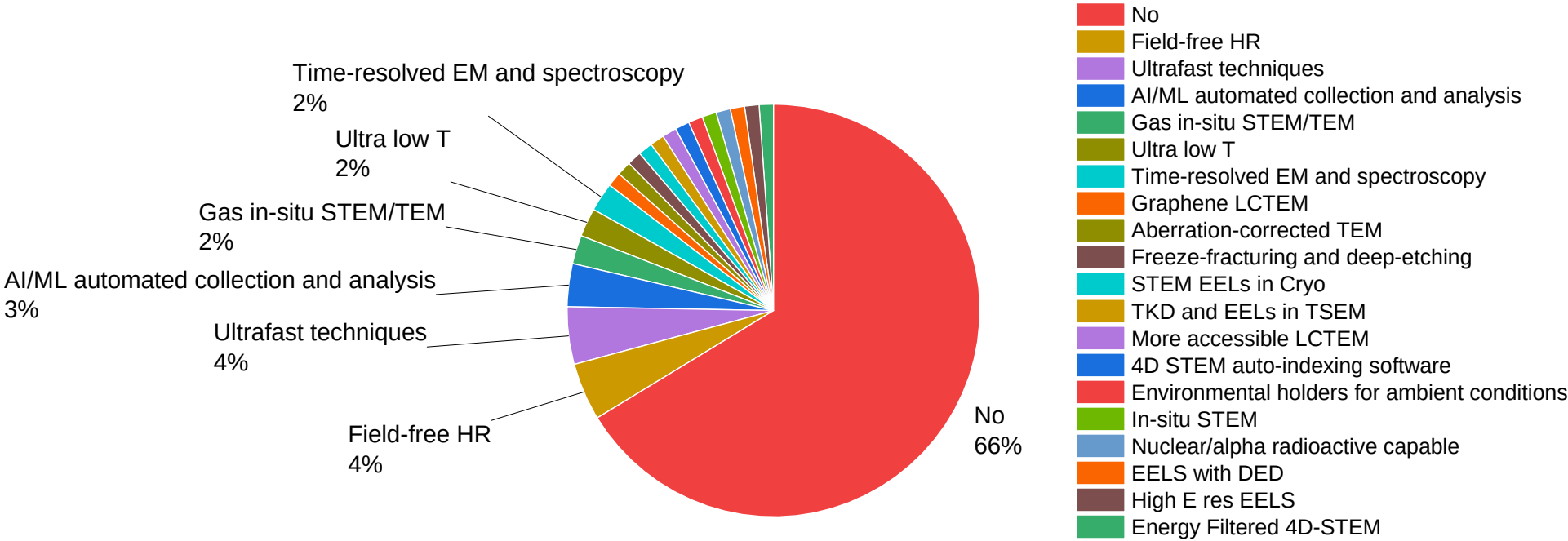
Which factors prevent you accessing the following techniques as much as you would like?



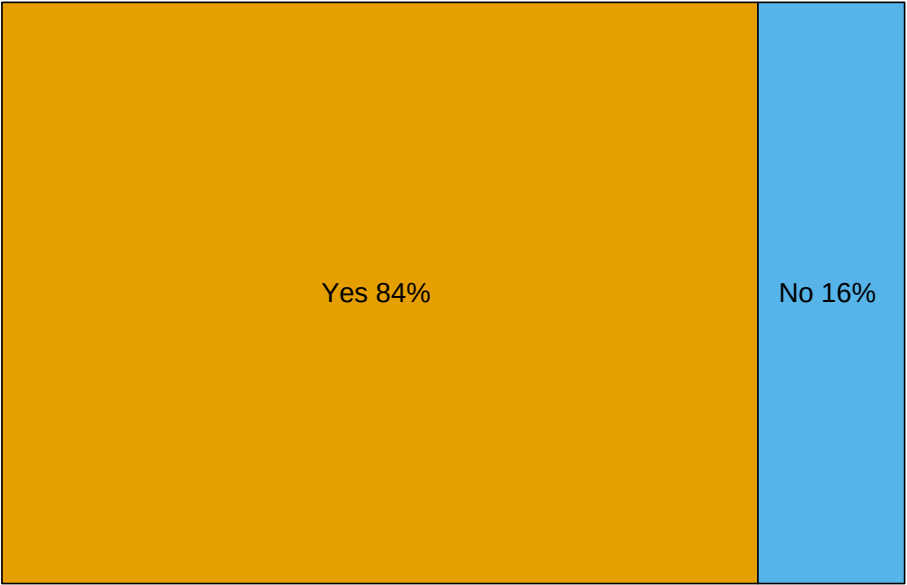
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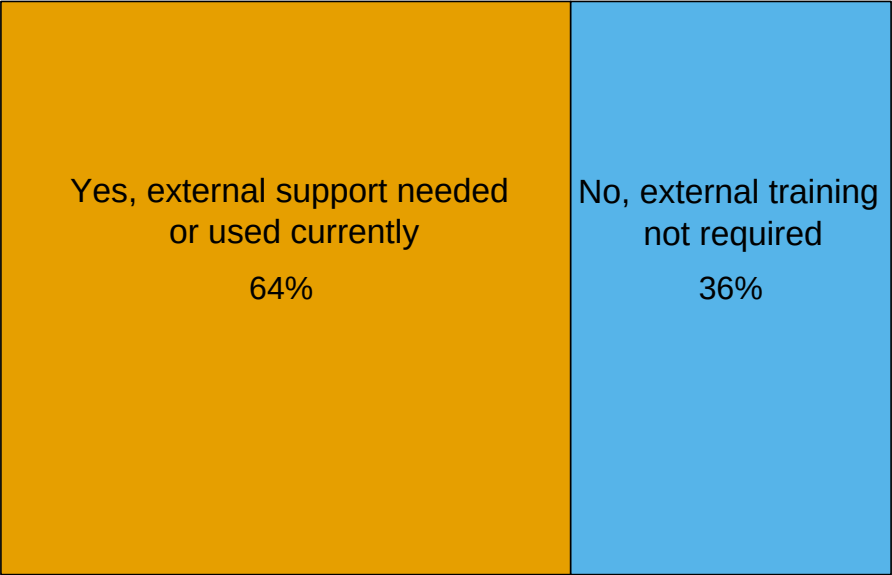
Are there electron microscopy techniques not currently available in the UK, but that you would like to use?



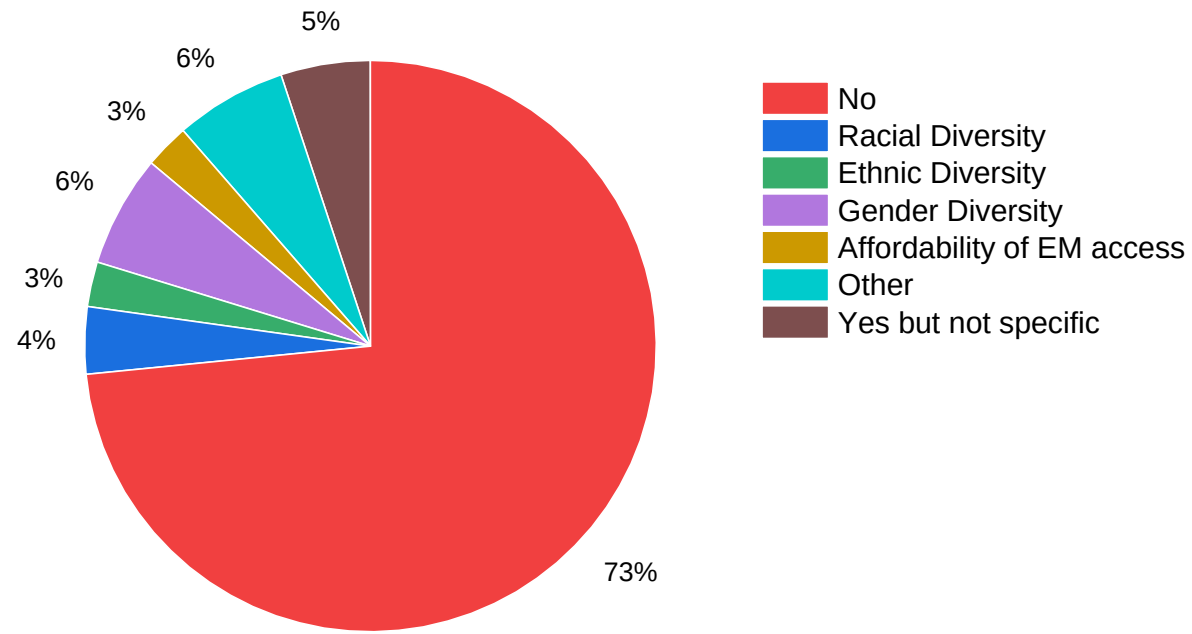
Do you have access to training (e.g. in instrument operation, data analysis, data management or theory) at your local facilities?



Do you have a need/demand for external training?



Are there any issues associated with Diversity in EM that you would like to raise?



Note: Yes but not specific = response was yes but did not give any other information

Q15

What role do you see for the provision of National EM facilities (or Specialist/Regional EM facilities) in the UK?

Some answers and key quotes:

Easy application/proposal submission portal and full support provided in a single facility from sample prep and transfer to characterise

Sharing best practice, training and support network

It would be very useful to have centres of excellence for technical and professional university staff to visit to learn best practice in how to run their local centres and to have strong links with more specialist expertise

EM facilities need to be strongly supported to provide access to emerging methodologies and instrumentation, and with dedicated support for staff. But this support must also be complemented by strong (independent) support for local/regional facilities - as upstream EM work is critical to ensuring efficient use of national capabilities.

A brilliant role - if they have access schemes without a limit on the number of projects you're allowed to apply for (but maybe on size of project after which you have to get a grant and pay for it).

Provision of the highest capability systems - the class leading resolution rather than standard systems. Unless local Universities continue to reduce support for core facilities and then National facilities have to support a much greater workload.

A key role for keeping the UK competitive

National Facilities are often exclusively committed and it is often inaccessible. Running a large EM Centre seems a good idea but in practice it does not provide academia with desired services. The accessibility and availability is one of the major concern.

Enough access for groups who primarily conduct their research using EM, as well as more information and training on various techniques for synthetic groups who may wish to use it to characterise their products

Regional: provision of free access to standard equipment; To provide world-leading techniques that would be impossible to sustain in a single academic or research institution.
National: provision of long-term (e.g. over night) experiments

This should be a move to model the synchrotron system, with dedicated instruments for specific tasks and general access via applications for high end instruments, with lower end instruments within departments for sample prep and screening for trips to other centres

They are a very important part of cutting edge techniques to be applied to increasing materials development requirements for climate and other technological challenges.
Also important that they form centres of excellence that can be referred and also training hubs for future microscopists.

Any centre should develop bespoke instruments and way away from off the shelf complete solutions from a single manufacturer to bespoke instruments built and maintained by in house staff, enabling adaptations of the instruments for more flexible and creative solutions to the research problems. Sample holders which can quickly and easily be moved between any of the instruments under vacuum to enable a single sample to be swiftly transferred.

Appropriate facilities for new/novice users, with systems in place to either train new users or provide microscopist time to run the analysis.

Survey results collated – analysis summary

- Field emission (SEM/TEM) instruments now more well established, as are Ga-FIBs.
- Large number of aberration corrected TEMs (1/3 of Labs surveyed)
- Increasing in-situ capability, increasing analytical capability
- Large number of machine < 10 years old (service/IT issues) but ca. 1/3 are older.
- Mixed funding model for replacement.
- Sample prep. increasingly offered as part of the service provision. Increasing evidence of study of mixed hard/soft samples.
- Relatively modest technical support and also academic support evident
- Evidence of support for RTP staff in terms of development
- Userbase typically in 100-200 range with increased evidence of external users and industry
- Increasing charged access evident, but issues for PhDs and ECRs. Tiered access charging is prevalent. However only 50% of labs re-cover more than 50% of their costs. Sustainability issue.
- More needs to be done in terms of ED&I
- Data processing/modelling/management increasingly important
- Additional Capacity is there but limited by trained users and staff support
- User appetite for external training and also use of National facilities.

Working Groups Ongoing

- **Training/RTPs WG & Access WG**
- EM/UK meeting/listserver ideal venue for single point of contact for RTPs and Training
- Need definitive list of Training courses and Access schemes
- Propose Training course gaps (e.g. Sample Prep, Equipment Maintenance, EM Data Processing) and potentially seek funding (Royce or other?)
- Look at best practice elsewhere, e.g. Australia Network <https://micro.org.au>
- Could we bid for a distributed access network (network plus type funding) or should we just suggest all new equipment bids have an access and training funds for external users?
- Initial Training Discussion document produced January 24

Working Groups Ongoing

- **Data/Modelling WG**
- Survey conducted at IOP's EMAG AGM at MMC 2023, with specific questions on data management/analysis/simulation provision in labs. The survey was completed by 21 EMAG members.
- Draft Report produced June 24
- **Overall Thoughts**
- Would some form of Networkplus – type grant help coordinate issues around Training/RTP development, Access and Data/Modelling ??